Eastern Research Group, Inc.

Air Program Support for Stage I and Stage II Programs in Massachusetts

Draft Final Report for Public Review

Prepared for:

Massachusetts Department of Environmental Protection

Prepared by:

Eastern Research Group, Inc.
de la Torre-Klausmeier Consulting

July 16, 2012

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Eastern Research Group, Inc.
3508 Far West Blvd., Suite 210
Austin, TX 78731

de la Torre-Klausmeier Consulting
1401 Foxtail Cove
Austin, TX 78704

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1.0 Executive Summary

In Massachusetts, gasoline dispensing facilities (GDFs) that dispense more than 10,000 gallons of gasoline per month are currently required to have Stage II vapor recovery systems. While Stage II controls have reduced the amount of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) released to the air during refueling, the emissions reduction benefits of these controls will continue to decrease as a greater proportion of motor vehicles in the Commonwealth are equipped with on-board refueling vapor recovery (ORVR) systems. Accordingly, MassDEP is considering changes to its air pollution control requirements for GDFs, with one option being removal or phasing out of Stage II controls.

ERG was tasked by MassDEP to provide technical assistance associated with the analysis of Stage II vapor recovery system emission benefits and the prevalence of ORVR systems within the Massachusetts vehicle fleet, as well as the analysis of potential enhancements to Stage I vapor recovery systems at GDFs. In addition, ERG was instructed to investigate whether removal of Stage II controls would result in disproportionate air quality impacts in environmental justice (EJ) communities, which may have a greater proportion of non-ORVR vehicles, and to recommend further research related to exposures to gasoline vapors in communities that may be disproportionately impacted by removal of Stage II systems.

1.1 Stage II and ORVR Assessment

As older vehicles without ORVR systems are retired and replaced with newer vehicles equipped with ORVR, the need for GDF Stage II controls becomes less over time. Recognizing that ORVR systems in the in-use vehicle fleet are increasingly prevalent, on May 16, 2012, EPA published a Final Rule[1] finding that ORVR systems are in widespread use (WSU) in the national vehicle fleet. EPA's rule allows states to terminate or phase out their Stage II programs by revising their state regulations and submitting a SIP revision to EPA seeking approval to terminate or phase out the program.

ERG analyzed the effect of removing, and the emissions impact and cost of retaining, Massachusetts' current Stage II program in the following years: 2013, 2015, and 2018. ERG's findings are summarized below.

- Statewide, ORVR systems alone will result in the same reductions as Stage II systems alone by approximately July of 2013.
- Statewide, Stage II in combination with ORVR will continue to reduce refueling emissions until 2015. Between July 2015 and July 2016, the continued presence of Stage II systems may cause emissions to increase relative to the ORVR alone case.

1.2 Stage I Assessment

ERG also estimated the additional reduction of VOC and toxic emissions that could be realized from improvements to MassDEP's Stage I control program. MassDEP's Stage I control program

[1] 77 Federal Register 28772

could be improved by implementing measures that go beyond current Stage I requirements, including the following:

- Require Stations to Implement Module 1 of the California Enhanced Vapor Recovery (CA EVR) - Module 1 of the California Enhanced Vapor Recovery (CA EVR) program contains enhancements to the Stage I program that are expected to increase control efficiencies from 95% to 98%.

- Require Vapor Leak Monitoring Systems - Continuous monitoring of GDF tank pressure and other parameters that indicate the presence of vapor leaks has the potential to reduce emissions.

- Require Pressure Management Systems (Emissions Processors) - Managing the pressure with a vapor processor reduces breathing losses and maintains the tank pressure close to ambient to avoid fugitive and vent cap emissions.

Based on our analysis ERG concluded the following:

- Adopting CA EVR requirements is estimated to reduce VOC emissions by 0.88 tons per summer day (TPSD) at an approximate cost of $12,000 per ton of VOC reduced. MassDEP could reduce the cost per ton of VOC reduced if it allowed GDFs to incrementally upgrade to CA EVR requirements as components are replaced or when facilities are significantly modified, instead of requiring stations to upgrade all components at a fixed time.

- Requiring continuous vapor leak monitoring systems is estimated to reduce VOC emissions by up to 6 TPSD at a cost of $1,000 per ton of VOC reduced.

- Tank pressure management systems have the potential to reduce VOC emissions at a relatively low cost per ton. However, additional data must be collected from GDFs to better characterize the benefits and cost per ton of VOC reduced for tank pressure management systems. Connecticut and New York are considering research that would involve setting up monitoring systems in leak-free GDFs that measure emissions from P/V valve vents.

1.3 Environmental Justice Area Impact Assessment

ERG conducted a preliminary assessment of whether removal of Stage II controls could result in disproportionate air quality impacts in Environmental Justice (EJ) areas. To do this, ERG analyzed whether EJ communities have a greater proportion of non-ORVR vehicles. Our analysis determined that EJ communities have a lower proportion of ORVR vehicles (73%) than non-EJ communities (77%), and GDFs located in EJ areas likely dispense a greater proportion of gasoline to non-ORVR vehicles (28%), as compared to GDFs located in non-EJ areas (26%). Both observations suggest that removal of Stage II controls could have a slight disproportionate impact on EJ areas due to refueling emissions. However, other factors (e.g., differences in vehicle miles traveled and fuel economy among the vehicle fleet) suggest that the difference in air quality impacts between EJ and non-EJ areas might actually be lower than these summary statistics imply. The expected air quality impacts associated with removing Stage II controls will likely vary considerably from one municipality to the next, as Section 5 of this report explains further.

2.0 Introduction

In Massachusetts, gasoline dispensing facilities (GDFs) that dispense more than 10,000 gallons of gasoline per month are currently required to have Stage II vapor recovery systems. While Stage II controls have reduced the amount of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) released to the air during refueling, the emissions reduction benefits of these controls will continue to decrease as a greater proportion of motor vehicles in the Commonwealth are equipped with on-board refueling vapor recovery (ORVR) systems. Accordingly, MassDEP is considering changes to its air pollution control requirements for GDFs, with one option being removal or phasing out of Stage II controls.

ERG was tasked by MassDEP to provide technical assistance associated with the analysis of Stage II vapor recovery system emission benefits and the prevalence of ORVR systems within the Massachusetts vehicle fleet, as well as the analysis of potential enhancements to Stage I vapor recovery systems at GDFs. In addition, ERG was instructed to investigate whether removal of Stage II controls would result in disproportionate air quality impacts in environmental justice (EJ) communities, which may have a greater proportion of non-ORVR vehicles, and to recommend further research related to exposures to gasoline vapors in communities that may be disproportionately impacted by removal of Stage II systems.

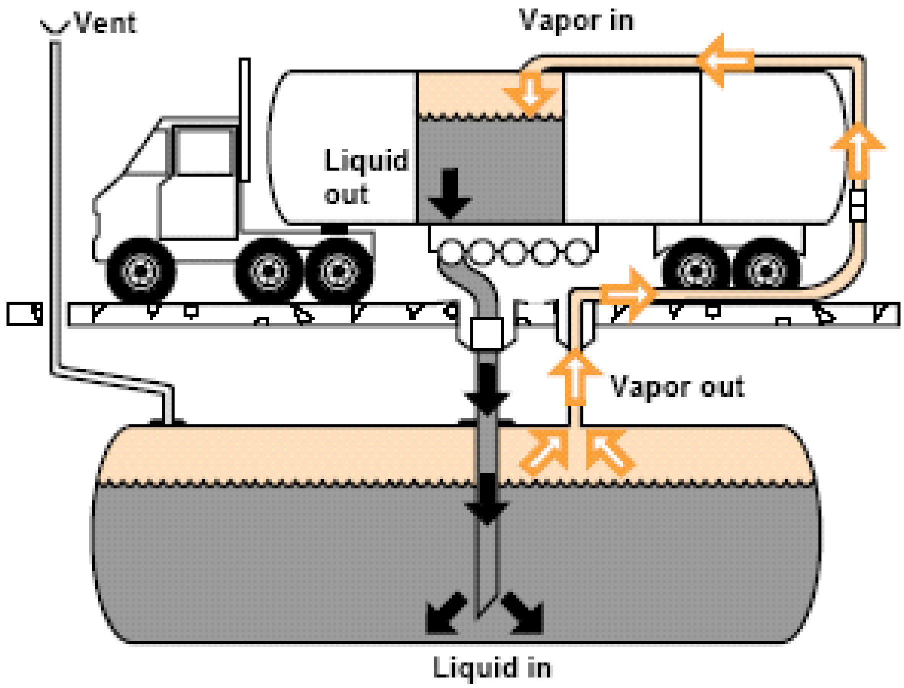
2.1 Background

The handling, storage, and dispensing of gasoline at GDFs can result in significant amounts of VOC and HAP emissions. These emissions are associated with two primary activities, and are referred to as Stage I and Stage II emissions, each of which has distinct emission control options.

2.1.1 Stage I Emissions and Controls

Stage I emissions occur when a GDF gasoline storage tank is filled, as gasoline vapors in the storage tank are displaced by liquid fuel. Stage I control systems route these vapors back to the tanker truck using a separate vapor connection, rather than venting them to the air, as shown in Figure 2-1.

Figure 2-1. Schematic of Stage I Vapor Recovery System

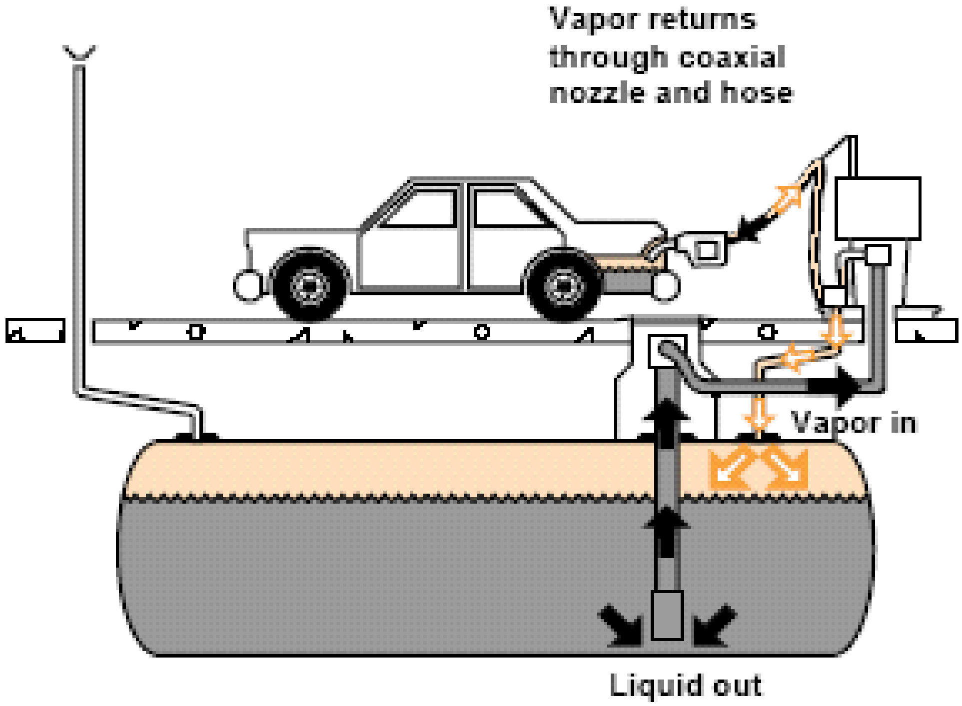


Stage I controls have been utilized since the 1980s. GDFs have also included improvements in tank pressure management, such as pressure/vacuum (P/V) valves to minimize tank breathing losses after refueling has occurred.

2.1.2 Stage II Emissions and Controls

Stage II emissions are similar to Stage I emissions. In this case gasoline vapors present in a vehicle's fuel tank are displaced by fuel dispensed from the pump. Stage II emission controls are also similar to Stage I controls, as illustrated in Figure 2-2. In this case a coaxial hose is utilized to transfer vapors instead of a separate vapor connection.

Figure 2-2. Schematic of Stage II Vapor Recovery System

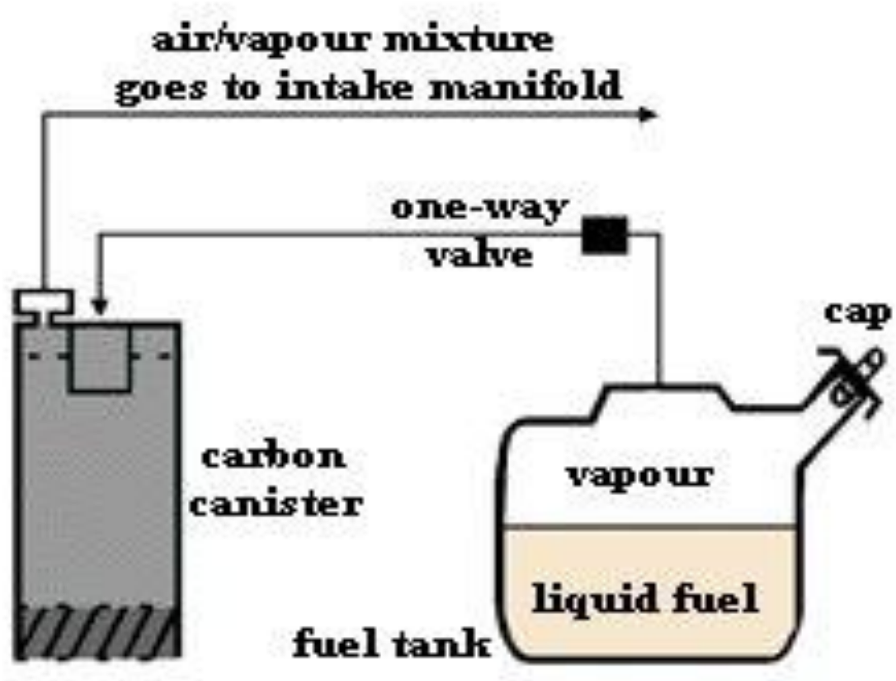


Stage II controls have been utilized since the 1990s. There are two main types of Stage II control systems, balance and vacuum assist. With a balance system, a bellow establishes a seal around the pump nozzle when it is inserted into the vehicle's refueling inlet. Vapors in the fuel tank simply displace fuel in the GDF tank. With a vacuum assist system, vapors from the vehicle's tank are actively sucked into the GDF tank through holes in the nozzle. The primary system used in Massachusetts is vacuum assist, although older balance systems are still in use.

2.1.3 ORVR Systems

ORVR systems offer an alternative to conventional Stage II systems. In this case, as vehicles are refueled vapors in the vehicle's fuel tank are routed to a carbon canister where they are stored for later purging and subsequent consumption in the engine. After the engine is started, vacuum is drawn through the carbon canister thereby sucking the air-vapor mixture into the intake manifold, to be combusted in the engine (see Figure 2-3). The majority of gasoline vehicles built since 1998 have ORVR systems, with the phase in completed by the mid-2000s.

Figure 2-3. Schematic of ORVR System



2.1.4 ORVR and Widespread Use Determination

As older vehicles without ORVR capability are retired and replaced with newer vehicles equipped with ORVR systems, the need for GDF Stage II controls becomes less over time. Recognizing that ORVR systems in the in-use vehicle fleet are increasingly prevalent, on May 16, 2012, EPA published a Final Rule[2] that determines that ORVR systems are in widespread use (WSU) in the national vehicle fleet and allows states to terminate their Stage II programs by revising their state regulations and submitting a SIP revision to EPA seeking approval to terminate the Stage II program. Current and former ozone nonattainment areas classified as serious and above are no longer required to implement Stage II vapor recovery programs.[3]

EPA used two analytical approaches to support the final WSU date:

1. When ORVR systems alone provide the same benefits as Stage II systems alone. EPA is assuming that Stage II systems are 77.4% effective, so WSU occurs when ORVR systems are projected to reduce refueling emissions by 77.4%.

2. When 75% of the gasoline is dispensed to ORVR equipped vehicles.

Using the first approach, EPA determined that WSU will occur in May of 2013. Using the second approach, EPA determined that WSU already occurred in April 2012. Based on the dates

[2] 77 Federal Register 28772
[3] EPA's Stage II vapor recovery program was required in approximately 40 areas, including ozone nonattainment areas and in the ozone transport region (OTR).

derived from these two basic approaches, EPA determined that ORVR was in widespread use on May 16, 2012, the date of the final rule. States that have implemented Stage II vapor recovery programs may now either keep the program or eliminate it or phase it out. However, because Stage II programs are part of an approved SIP, a state must continue to implement the program until EPA approves a SIP revision removing the requirement. EPA is expected to issue guidance to states concerning how to develop approvable SIP revision seeking to remove or phase out an existing program. States will be required to demonstrate compliance with specific Clean Air Act (CAA) provisions in order for EPA to approve a SIP revision.

3.0 Emissions Impact of Retaining Massachusetts' Current Stage II Program

ERG analyzed the VOC and toxic emissions impact and the cost to GDFs of retaining Massachusetts' current Stage II program through the following years: 2013, 2015, and 2018. This task involved three steps: 1) estimating gasoline throughput by station Stage II system type; 2) evaluating emission reductions under the current Stage II program, and 3) estimating the costs of continuing the current program. The findings for each of these components are discussed below.

3.1 Gasoline Consumption by Type of Stage II System

Emissions and emission reductions for different GDF controls are proportional to gasoline throughput. ERG calculated gasoline throughput by type of Stage II system. Stage II systems are grouped into two main categories: 1) ORVR Compatible and 2) Not-ORVR Compatible. With a vacuum assist system, vapors from the vehicle's tank are drawn into a GDF tank through holes in the nozzle. When a vehicle with ORVR is refueled at a GDF with a vacuum assist system that is not ORVR compatible, ambient air from the vicinity of the GDF nozzle will be drawn back into the GDF storage tank. This air dilutes the concentration of gasoline vapors in the headspace of the storage tank, causing additional liquid gasoline in the storage tank to evaporate, which increases the storage tank pressure. If the tank pressure increases above the positive setting of GDF's Pressure/Vacuum (P/V) valve, the storage tank will vent gasoline vapors to the atmosphere.

Vacuum assist systems that use either Healy 400 ORVR or Healy 800 ORVR nozzles are ORVR compatible. These nozzles sense when a vehicle with ORVR is being refueled and prevent ingestion of air during refueling. Stage II balance systems are also ORVR compatible. With a balance system, a bellow (or a boot) establishes a seal around the nozzle. When a vehicle is refueled, vapors in the vehicle's tank simply displace fuel in the GDF tank, and no additional vapor is formed.

The estimated annual fuel consumption for 2011 by type of Stage II system is shown on Table 3-1.

Gasoline throughput is skewed towards the high volume stations, with the top two throughput categories dispensing 72% of the gasoline but only accounting for 37% of the total number of GDFs. Table 3-1 shows that an estimated 81% of the gasoline state-wide is dispensed at GDFs that have Stage II systems that are not ORVR compatible.

Table 3-1. Statewide Gasoline Consumption (2011) [4]

Throughput Category [5](gal/yr)	# GDFs				Annual Throughput				
	Not ORVR Compatible	ORVR Compatible	Total	% of Stations	Average Gals/yr/GDF[6]	Not ORVR Compatible	ORVR Compatible	Grand Total	% of Throughput
Less than 120,000	11	587	598	20%	60,000	660,000	35,220,000	35,880,000	1%
120,000 to 240,000	34	80	114	4%	180,000	6,120,000	14,400,000	20,520,000	1%
240,001 to 500,000	181	190	371	12%	370,000	66,970,000	70,300,000	137,270,000	5%
500,001 to 1,000,000	591	223	814	27%	750,000	443,250,000	167,250,000	610,500,000	21%
1,000,001 to 2,000,000	768	126	894	29%	1,500,000	1,152,000,000	189,000,000	1,341,000,000	46%
Greater than 2,000,000	213	28	241	8%	3,200,000[7]	681,600,000	89,600,000	771,200,000	26%
Grand Total	**1798**	**1234**	**3032**			**2,350,600,000**	**565,770,000**	**2,916,370,000**	
		Percent of Gasoline Dispensed				**81%**	**19%**		

[4] Department of Revenue reported that annual taxable gasoline sales were 2,770,000,000 gallons in 2011.
[5] MassDEP maintains a database of the type of Stage II systems at GDFs and the gasoline throughput as reported by GDFs for the throughput categories shown in this column. Gasoline consumption estimates based on the MassDEP GDF database agree well with Department of Revenue's records on gasoline sales by month, within approximately 5%.
[6] Average value of throughput range except for > 2,000,000 gallons per year.
[7] The value of 3,200,000 was based on a survey ERG performed on GDFs in Connecticut. It represents the average throughput for GDFs that dispensed more than 2,000,000 gallons per year.

3.2 Emission Reductions for Current Stage II Program

Using EPA's latest mobile source emissions model, MOVES 2010a, ERG estimated emissions reductions for continuing the current Stage II program for calendar years 2013, 2015, and 2018. ERG ran MOVES for Middlesex and Hampden Counties for the following cases:

- Uncontrolled baseline (no ORVR or Stage II)
- Stage II Only
- ORVR Only

Middlesex and Hampden counties were chosen by MassDEP to represent eastern and western Massachusetts, respectively. These two counties can be used to approximate statewide Stage II refueling emissions without the need to model all 14 counties.[8]

Using MOVES model outputs, ERG estimated: 1) the percent reduction in refueling emissions from ORVR, and 2) the fraction of gasoline that is dispensed to ORVR equipped vehicles. (See Appendix A for further details regarding MOVES modeling.) These are the same parameters that EPA calculated in its WSU analysis. Table 3-2 shows results by year for the two counties. The results are nearly identical for the two counties for both parameters. The minor differences are due to slight variations in vehicle populations, temperatures, and fuel formulations between eastern and western Massachusetts. Note that the results are for approximately July 1 of each scenario year based on MOVES outputs. As a point of comparison, EPA determined that ORVR would achieve a 77.4% control efficiency by May 2013, and that by April 2012, 75% of the gasoline will be dispensed to ORVR equipped vehicles in the national fleet.

Table 3-2. Percent Reduction in MA VOC Refueling Emissions from ORVR Based on MOVES

Year	% Reduction from Stage II Alone	% Reduction from ORVR Alone		ORVR Penetration (% of Gasoline)	
		Hampden	Middlesex	Hampden	Middlesex
2013	84%	83%	83%	85%	85%
2015	84%	88%	89%	90%	90%
2018	84%	92%	92%	94%	94%

To estimate tons per day reductions for the current Stage II program, ERG calculated refueling emissions in terms of lb./1,000 gallons of gasoline dispensed. The emission factors used to calculate statewide emissions are based on a weighted average of the Middlesex and Hampden County emission factors. The Middlesex emission factors are weighted by 64% and Hampden emission factors are weighted by 36%. This weighting was determined by MassDEP based on

[8] Analyses performed by MassDEP have shown that MOVES runs performed using these two representative counties and extrapolated statewide using county VMT fractions are within 1% of the results obtained by totaling the MOVES results from 14 individual counties.

the fraction of vehicle miles travelled from eastern counties (represented by Middlesex) compared to the western counties (represented by Hampden.)

For the Stage II scenarios, ERG adjusted the MOVES emission estimates for incompatibility excess emissions. As discussed in Section 3.1, most vacuum assist Stage II systems are not compatible with on-board refueling vapor recovery (ORVR). The increased emissions that occur due to the dilution of the storage tank with air from ORVR vehicles are termed incompatibility excess emissions (IEE). IEE is limited to vacuum assist systems without ORVR compatible nozzles[9]. As shown in Table 3-1, (81%) of the gasoline dispensed in Massachusetts is dispensed at GDFs with vacuum assist systems that are not ORVR compatible.

ERG evaluated two values for IEE: 0 (no IEE) and 0.86 lb.VOC/1,000 gallons. The value of 0 establishes the upper bound for Stage II control effectiveness and provides a conservative analysis that EPA may require for SIP purposes. The value of 0.86 lb. VOC per 1,000 gallons was developed by the California Air Resources Board (CARB) for vacuum assist systems that are not ORVR compatible[10, 11]. The factor of 0.86 lb. VOC/1,000 gallons applies only to gasoline that is dispensed to ORVR vehicles at GDFs that are not ORVR compatible. Note that Veeder-Root and ARID, vendors of GDF tank pressure management systems, have reported much higher IEE factors, between 1.5 and 5 lb./1,000 gallons. Because Veeder-Root's and ARID's estimates have not been independently verified, ERG did not use their IEE factors in our analysis.

Figure 3-1 shows fleet average refueling emissions rate in lb./1,000 gallons for the ORVR alone case compared to the Stage II alone case. For the Massachusetts fleet, emissions for the ORVR alone case equal the Stage II alone case in July 2013.

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[9] Vacuum assist systems that use either Healy 400 ORVR or Healy 800 ORVR nozzles are ORVR compatible.
[10] CARB. *Preliminary Draft Test Report, Total Hydrocarbon Emissions from Two Phase II Vacuum Assist Vapor Recovery Systems During Baseline Operation and Simulated Refueling of Onboard Refueling Vapor Recovery (ORVR) Equipped Vehicles*. June 1999. Note that CARB's value was based on tests where the air/liquid (A/L) varied between 1.0 and 1.2. IEE are in addition to storage tank breathing losses.
[11] In the early 2000s, the American Petroleum Institute suggested that the IEE factor was between 0.42 to 0.72, but at that time contended that ORVR incompatibility was not an issue.

Figure 3-1

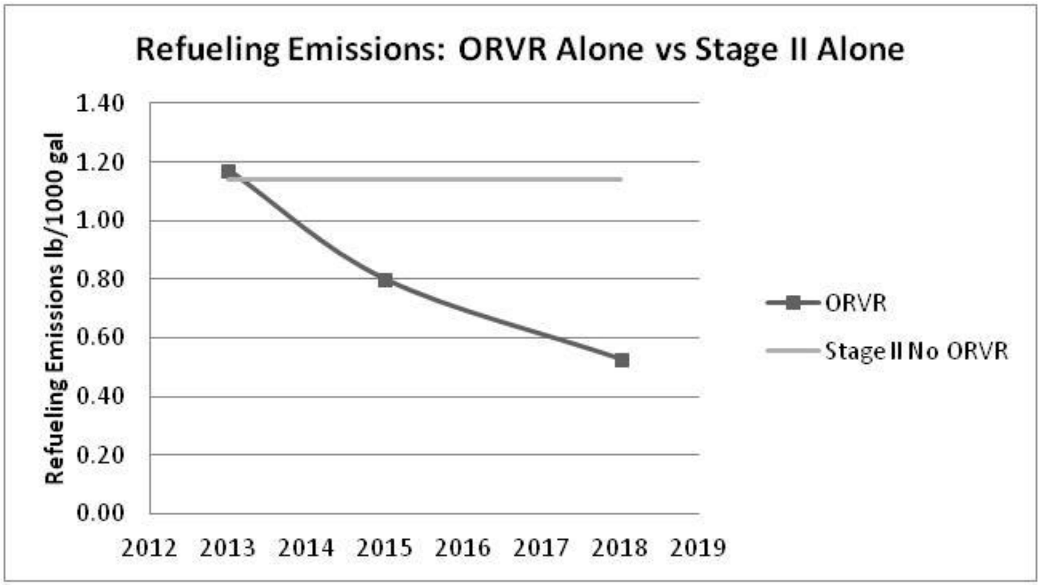


Figure 3-2 compares emissions in lb./1,000 gallons for the ORVR alone case with the Stage II plus ORVR case. With an IEE=0.86 lb./1,000 gallons, the Stage II plus ORVR case will have greater emissions than the ORVR alone case between July 1, 2015 and July 1, 2016.

Figure 3-2

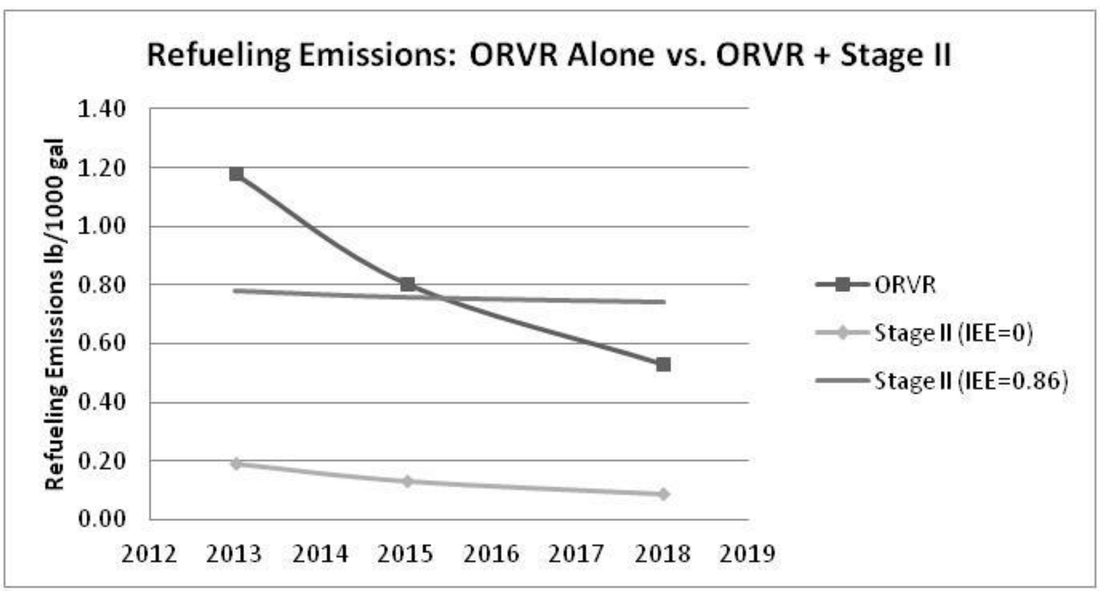
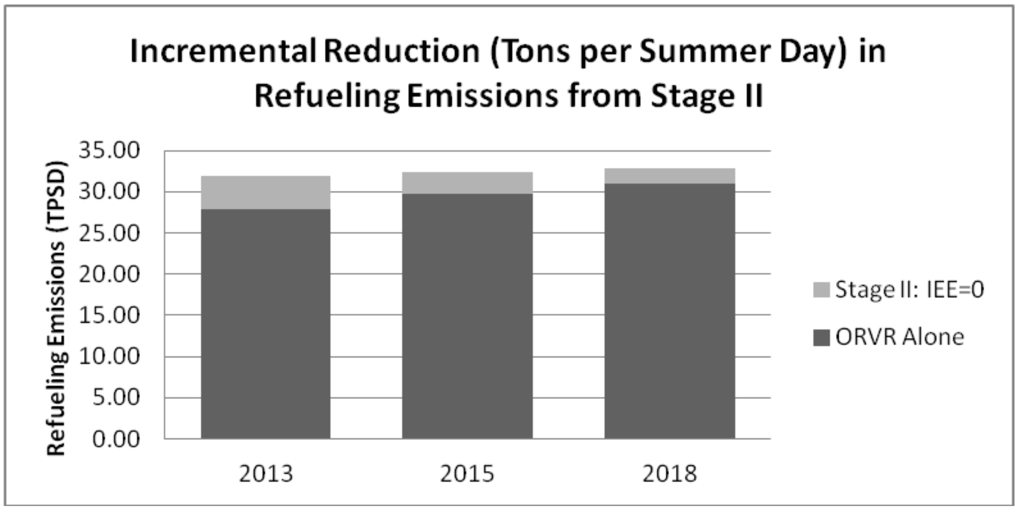


Table 3-3 shows estimated statewide VOC emission reductions from the current Stage II program. Results for the IEE=0 lb./1,000 gallons case are shown graphically in Figure 3-3. Table 3-3 provides the range of emission reductions that Stage II will continue to provide in Massachusetts taking into account the IEE.

Table 3-3. Statewide VOC Emission Reductions (Tons per Summer Day) for Continuing Current Stage II Controls

Year	ORVR Alone	Additional Reduction from Stage II (Tons per Summer day)	
		IEE=0 lb./1,000 gal	IEE=0.86 lb./1,000 gal
2013	27.90	4.74	1.92
2015	29.69	3.24	0.24
2018	31.00	2.13	-1.00 (emissions increase)

Figure 3-3



ERG was also asked to estimate the impacts of removing Stage II on the emissions of hazardous air pollutants (HAPs). The HAPs found in greatest quantities in refueling emissions are n-hexane, toluene, and benzene. N-hexane and toluene account for the highest amounts of HAPs in GDF refueling emissions but benzene is considerably more toxic and is, therefore, considered the “risk driver” for the HAPs in refueling vapors. Benzene is a known carcinogen and is the first HAP that would be expected to have air concentrations greater than any health-based screening value, whether for acute or chronic exposure durations. Table 3-4 shows the estimated reductions of benzene with ORVR alone and with ORVR and Stage II.

Table 3-4. Statewide Benzene Emission Reductions (lbs per Summer Day) for Continuing Current Stage II Controls

Year	ORVR Alone	Additional Reduction from ORVR + Stage II (lbs. per Summer day)	
		IEE=0 lb./1,000 gal	IEE=0.86 lb./1,000 gal
2013	217.62	36.97	15.01
2015	231.56	25.27	1.90
2018	241.83	16.64	-7.76 (emissions increase)

3.3 Costs to Continue Stage II Systems

Table 3-5 presents estimated costs for continuing Stage II systems based on publicly available studies. EPA's study is the most recent and the assumptions are well documented, so ERG selected it as the basis for evaluating the costs of continuing Stage II in Massachusetts. EPA accounted for costs for hardware replacement, operating and maintenance, and vapor recovery fuel credit. The model station that was the basis for EPA's estimate pumped 120,000 gallons per month, had 10 nozzles and three underground storage tanks. Note that EPA's annual cost estimate of $2,977 includes a $1,230 credit per GDF for fuel recovery. An annual cost per GDF of $4,207 was used in the calculations of the cost per ton of VOC reduced and then a fuel credit specific to Massachusetts was applied to this cost. This credit assumed a gasoline cost of $4.00/gallon.

Table 3-5. Annual Costs to GDFs for Continuing Current Stage II Program

Source	Annual Cost (with fuel savings)
Low: New York State[12]	$2,000
High: API[13]	$4,410
EPA[14]	$2,977 ($4,207 without fuel credit)

The cost per ton of VOC reduced associated with continuing the current Stage II program was calculated for two IEE scenarios: 0 (no IEE) and 0.86 lb./1,000 gallons. Emission reductions and costs per ton are extremely sensitive to the assumed IEE factor.

[12] Part 230 -- Gasoline Dispensing Sites and Transport Vehicles, Stakeholder Meeting; New York Department of Environmental Protection, December 7, 2010.

[13] Refueling Emission Controls at Retail Gasoline Dispensing Stations and Cost-Benefit Analysis of Stage II in Connecticut, Tech Environmental, Inc., September 24, 2007

[14] Widespread Use for Onboard Refueling Vapor Recovery and Stage II Waiver; USEPA, July 8, 2011. Costs include fuel savings of $930/yr.

Table 3-6. Cost per Ton of VOC Reduced for Continuing Stage II: 2013

Throughput Category (gal/yr)	(Stage II Benefit tons/yr)		$/ton	
	IEE=0	IEE=0.86	IEE=0	IEE=0.86
Less than 120,000	18	7	$105,959	$262,902
120,000 to 240,000	10	4	$35,963	$90,503
240,001 to 500,000	68	28	$17,991	$46,239
500,001 to 1,000,000	302	123	$9,364	$24,992
1,000,001 to 2,000,000	664	270	$5,164	$14,648
Greater than 2,000,000	382	155	$2,933	$9,152
ALL	**1444**	**586**	**$7,514**	$20,435

Table 3-7. Cost per Ton of VOC Reduced for Continuing Stage II: 2015

Throughput Category (gal/yr)	Stage II Benefit (tons/yr)		$/ton	
	IEE=0	IEE=0.86	IEE=0	IEE=0.86
Less than 120,000	12	1	$155,668	$2,088,821
120,000 to 240,000	7	1	$53,237	$725,042
240,001 to 500,000	46	3	$26,938	$374,883
500,001 to 1,000,000	207	16	$14,314	$206,807
1,000,001 to 2,000,000	454	34	$8,168	$124,980
Greater than 2,000,000	261	20	$4,903	$81,509
ALL	**987**	**74**	**$11,606**	**$170,760**

Table 3-8. Cost per Ton of VOC Reduced for Continuing Stage II: 2018

Throughput Category (gal/yr)	Stage II Benefit (tons/yr)		$/ton	
	IEE=0	IEE=0.86	IEE=0	IEE=0.86
Less than 120,000	8	-4	$237,045	Not Meaningful
120,000 to 240,000	5	-2	$81,517	Not Meaningful
240,001 to 500,000	31	-14	$41,585	Not Meaningful
500,001 to 1,000,000	136	-63	$22,417	Not Meaningful
1,000,001 to 2,000,000	299	-139	$13,085	Not Meaningful
Greater than 2,000,000	172	-80	$8,128	Not Meaningful
ALL	**650**	**-303**	**$18,306**	Not Meaningful

3.4 Summary

Following are the major results of this analysis:

- ORVR systems alone will result in the same reductions as Stage II systems alone around July 2013.
- Stage II in combination with ORVR will continue to reduce refueling emissions until 2015. Between July 1, 2015 and July 1, 2016, Stage II may cause emissions to increase over the ORVR alone case. This date is based on CARB's recommended IEE factor of 0.86 lb. per 1,000 gallons is used.
- The cost-effectiveness of Stage II controls declines significantly between 2013 and 2015.

4.0 Additional Reduction of VOC and Toxic Emissions That Could be Realized from Improvements to MassDEP's Stage I Control Program

ERG estimated the additional reduction of VOC and toxic emissions that could be realized from improvements to MassDEP's Stage I control program. Outside of vehicle refueling emission losses, which are captured by Stage II and ORVR systems, there are two main sources of emissions at GDFs:

- Filling losses, and
- Tank breathing losses.

Filling losses occur when fuel from tanker trucks are off-loaded into GDF storage tanks. Vapors in the GDF storage tank are displaced by fuel pumped into the tank. Currently, GDFs in Massachusetts have Stage I controls which are certified to capture 95% of the vapors displaced from by the fuel.

A second source of vapor emissions from service stations is underground tank breathing. Breathing losses occur daily and are attributable to gasoline evaporation and barometric pressure changes. Breathing losses are reduced but not totally eliminated by P/V valves, which are required on GDFs in Massachusetts.

4.1 Possible Stage I Enhancements

MassDEP's Stage I control program could be improved by implementing measures that go beyond current Stage I requirements. Currently, Massachusetts' regulations require GDFs to have the following Stage I components:

- **Two point Stage I systems:** Required on all GDFs with vacuum assist Stage II systems and above ground storage tank systems.
- **Rotatable Fill & Vapor Adaptors:** Required on all vacuum assist systems.
- **Spill Containment Boxes (Buckets):** Required on all systems.
- **Submerged fill pipes:** Required on all systems. Must be proper length and angle cut.
- **Coaxial systems:** Are only allowed on balance systems used with underground storage tanks.
- **Pressure Vacuum (P/V) Vent Valve Caps:** Required on all vents at GDFs with Stage II systems.

The following provides a detailed discussion of additional measures that could be adopted to further reduce Stage I emissions in Massachusetts.

4.1.1 Require Stations to Implement Module 1 of the California Air Resources Board Enhanced Vapor Recovery (CA EVR)

Module 1 of the California Enhanced Vapor Recovery (CA EVR) program contains enhancements to the Stage I program that are designed to increase control efficiencies from 95% to 98%. These enhancements include:

- **Drop tube with Overfill Protection Specification**: CA EVR requires overfill protection devices on drop tubes. These devices use a valve to shut off liquid flow when the underground storage tank is being filled.
- **Pressure/Vacuum Relief Valves (P/V Valves) on Vent Pipes**: Vent pipes are required for gasoline underground storage tanks to allow venting of vapors if the underground tanks develop significant pressure. Although GDFs in Massachusetts are required to have P/V valves, the valves are not required to meet CA EVR specifications.
- **Spill Containment Boxes**: GDFs in Massachusetts must have spill containment boxes but they are not required to meet the CA EVR standards for product containment boxes, which limit the leak rate to < 0.17 cubic feet/hour at + 2.0 inches H_2O and prohibit any standing fuel in the containment box of product connectors. CA Phase I EVR orders also prohibit drain valves in the spill boxes of vapor connectors.
- **Connectors and Fittings**: Loose connectors and fittings can lead to leaks in the underground tank vapor. This CA EVR requirement ensures connectors and fittings shall be leak-free as determined by either leak detection solution or by bagging the fittings and observing inflation of the bag.
- **Phase I Adaptor Specifications**: All GDFs in Massachusetts are currently required to use swivel adaptors that meet CA EVR standards. Phase I adaptors are the connection points for the cargo tank truck to the service station underground storage tank. The adaptors tend to become loose during the bulk drop as the cargo tank driver connects and disconnects the hoses for the fuel transfer. This is one of the commonly identified causes of leaks from vapor recovery systems, as well as a contributing factor to reduced effectiveness of the Phase I system. CA EVR regulations include a requirement for 360 degree rotatable Phase I vapor and product adaptors.
- **Fuel Blend Compatibility**: CA EVR components must be demonstrated to be compatible with fuel blends approved for use and commonly used in California, including fuels meeting the recently adopted Phase III fuels requirements. Fuel used in Massachusetts will be compatible with fuel assumed in the CA EVR systems.

At least five vendors have been approved by the California Air Resource Board to provide the above Stage 1 EVR systems.[15] As noted above, all Massachusetts GDFs have CA EVR swivel adaptors.

[15] The following CARB Executive Orders have been issued for CA EVR Phase I systems: VR-101 Phil-Tite, VR-102 OPW, VR-103 EBW, VR-104 CNI, VR-105 EMCO Wheaton.

4.1.2 Require Continuous Vapor Leak Monitoring systems

Continuous monitoring of GDF tank pressure and other parameters that indicate the presence of vapor leaks has the potential for further emissions reductions. Based on GDF inspection results in MA and other states, many GDFs have leaks in their vapor control systems. These leaks reduce the efficiency of Stage I systems in controlling filling losses when fuel is delivered to the GDF. In addition, these leaks reduce the effectiveness of P/V valves in reducing breathing losses.

Two vendors provide CARB certified systems to continuously monitor GDFs for leaks: 1) Franklyn Fueling Systems and 2) Veeder-Root. Because these systems have not been used on GDFs outside of California stakeholders have expressed concerns over the reliability of these systems in winter when they are exposed to snow and slush and extremely cold temperatures. ERG believes these systems should work reliably in Massachusetts as they require tank pressure sensors and other hardware that are no more fragile than the hardware used in underground storage tank monitoring systems, which have operated reliably in Massachusetts in the winter.

4.1.3 Require Pressure Management Systems (Emissions Processors)

Managing tank pressure from gasoline in a tank with a vapor processor reduces breathing losses and maintains the tank pressure close to ambient pressure. This avoids fugitive and vent cap emissions. Several vendors[16] offer tank pressure management systems that minimize tank breathing losses. ARID and Veeder-Root offer systems that use either membranes or carbon canisters to separate vapors from the breathing losses. The vapors are returned to the GDF tank. Hirt offers a system that incinerates the vapors.

4.2 Estimated Emission Reductions from Stage I Improvements

ERG estimated the emission reductions for the following enhancements to Stage I systems at GDFs:

- Require upgrade to CA EVR requirements.
- Require Continuous Vapor Leak Monitoring Systems.
- Require Tank Pressure Management Systems.

4.2.1 Upgrade to CA EVR Module 1 Requirements

The emission reductions resulting from requiring GDFs to install Stage I equipment that meets CA EVR requirements for Module 1 were estimated by assuming Stage I control efficiency increases from 95% to 98%. An uncontrolled filling loss emission factor of 7.3 lb. VOC/1,000 gallons was assumed, based on the most recent version of AP-42. Rule penetration and rule effectiveness factors of 99.8% and 84.0% used in Massachusetts' most recent (2008) emission

[16] A partial list includes Veeder-Root, ARID, and Hirt.

inventory estimates for gasoline distribution were applied.[17] Table 4-1 presents the estimated statewide emission reductions from requiring GDFs to upgrade to CA EVR requirements. As all GDFs in Massachusetts have swivel adaptors that meet CA EVR requirements, these estimates represent the upper bound of the benefits from requiring GDFs to use CA EVR equipment.

Table 4-1. Upper Bound Statewide Emission Reductions from Upgrading to CA EVR Module 1 Requirements

Throughput Category (gal)	# GDFs	Average Annual Throughput	Total Annual Throughput	VOC Emission Reductions	
				Tons per year	Tons per Summer Day
Less than 120,000	598	60,000	35,880,000	3.29	0.01
120,000 to 240,000	114	180,000	20,520,000	1.88	0.01
240,001 to 500,000	371	370,000	137,270,000	12.60	0.04
500,001 to 1,000,000	814	750,000	610,500,000	56.04	0.18
1,000,001 to 2,000,000	894	1,500,000	1,341,000,000	123.10	0.40
Greater than 2,000,000	241	3,200,000	771,200,000	70.79	0.23
Grand Total	**3,032**		**2,916,370,000**	**268**	**0.88**

4.2.2 Require Continuous Monitoring Systems for GDF Vapor Leaks

EPA has not provided guidance on how to estimate the emission reductions from continuous monitoring systems for GDF vapor leaks. ERG estimated benefits for these systems by combining estimates of the percentage of GDFs that have leaks (as indicated by failure of the pressure decay and P/V valve tests conducted during 2011 certification tests in Massachusetts) with the estimated impact of leaks.

Condition of Vapor Recovery Systems – The emission benefits for continuous vapor monitoring systems depends on the condition of current Stage I control systems. Data from Massachusetts and other states indicate that Stage I systems quickly develop leaks and other malfunctions that cause them to fail system performance tests.

Massachusetts Test Results – Massachusetts DEP requires GDFs to report the initial results of their annual Stage I/II certification tests. Table 4-2 summarizes the percent of stations that fail their initial certification test in Massachusetts by system type (assist or balance). Facilities that fail the initial tests are required to repair and retest with passing results before submitting an annual certification form. About 2/3 of the stations failed their initial certification test in 2011. The high volume stations have higher failure rates than the lower volume stations. As shown on Table 4-3, from 2001 through 2011, 66% to 82% of the GDFs failed their initial annual certification tests. The primary test failures were Pressure Decay and Air/Liquid Ratio. Pressure decay tests failed mostly because of leaking hanging hardware components (a Stage II problem), or leaking tank top components (a Stage I problem). The Air/Liquid Ratio tests failed because of

[17] Control efficiency is the percentage of a source category's emissions that are controlled by a control method. Rule effectiveness is an adjustment to the control efficiency to account for failures and uncertainties that affect the actual performance of the control method. Rule penetration is the percentage of the nonpoint source category that is covered by the applicable regulation.

broken or improperly calibrated Dispenser Vacuum Motors or defective nozzles, both of which are Stage II related.

From May 2002 through October 2003, Massachusetts required new or significantly modified GDFs with vacuum assist Stage II systems to receive a certification test 120 days after they were initially certified. Massachusetts gathered Stage II “120 day” test reports from the Stage II testing companies for the period May 2002 through October 2003 and the results of these tests are shown on Table 4-4. Results indicate that over half (56%) of the recently certified GDFs failed certification tests 120 days later. The most common failure was for the pressure decay test, which accounted for 82% of the test failures. A breakdown of the sources of the leaks is not available, so we cannot determine if the pressure decay failures are due to ineffectiveness of Stage II systems or Stage I systems. P/V valve test failures account for 4% of the test failures.

Table 4-2. Results of Initial Annual GDF Certification Tests in Massachusetts: 2011

	% of Initial Test Failures		
Station Throughput (gal/yr)	**Assist**	**Balance**	**All**
Less than 120,000	51%	54%	53%
120,000 to 240,000	51%	65%	60%
240,001 to 500,000	68%	72%	70%
500,001 to 1,000,000	68%	79%	70%
1,000,001 to 2,000,000	69%	83%	71%
Greater than 2,000,000	77%	50%	76%
All	**69%**	**64%**	**67%**

Table 4-3. Historical Results of Initial Annual GDF Certification Tests in Massachusetts

Year	% Fail
2001	82%
2002	78%
2003	75%
2004	67%
2005	76%
2006	78%
2007	78%
2008	73%
2009	71%
2010	66%
2011	67%

Table 4-4. Results of 120 Day GDF Certification Tests in Massachusetts

Failure Reason	#	% of Tests	% of Failures
Air/Liquid Ratio (Impacts Effectiveness of Stage II systems)	17	17%	31%
Pressure Decay (Impacts Effectiveness of Stage I and II systems)	45	46%	82%
P/V Cap (Impacts Effectiveness of Stage I and II systems)	2	2%	4%
Any Failure	**55**	**56%**	**100%**

Connecticut Test Results – ERG reviewed two sources of information on the condition of GDFs in Connecticut: results of official certification tests and results of additional GDF tests performed by dKC:

- Table 4-5 summarizes the initial results of GDF inspections that were witnessed by CT DEEP since December 20, 2010. Overall, 70% of the GDFs failed inspection. The most common failure reasons were the tank decay test (45%), followed by air/liquid test (A/L) (14%).
- In 2011, dKC commissioned additional GDF tests to help determine when key components of the vapor control system start to deteriorate. These tests were performed approximately 2 months and 4 months after the station received its certification test. Two stations participated: one was a government station with a balance system; the other was a private station with a vacuum assist system. Table 4-6 summarizes results of these tests. None of the tests had an overall result of pass.

Table 4-5. Results of Triennial GDF Inspections in Connecticut

Parameter	# and % of Failures					
	Fail for Any Item	Affects Stage I and Stage II		Affects Stage II Only		
		Decay	P/V Cap	Dry Blockage	Wet Blockage	A/L
#	111	72	10	5	6	23
% of Tests	70%	45%	6%	3%	4%	14%

Table 4-6. Results of Bi-monthly GDF Inspections in Connecticut

Station/Stage II Type	Test date	Overall Result	Failed items
J and A Gas (Vacuum Assist)	6/2/11	Fail	A/L Test
	8/23/11	Fail	A/L Test
DOT Newington (Balance)	4/25/11	Fail	P/V valve
	7/14/11	Fail	Decay, P/V valve, torn hose
	11/9/11	Fail	Decay, P/V valve

New Hampshire Test Results – According to vapor release research conducted by New Hampshire, GDF repairs last an average of 58 days. Overall findings of New Hampshire's research found:

- Inspections and testing failed to fix key leaks;
- Most leaks required the station to upgrade hardware (i.e. hoses, nozzles, breakaways);
- Gasoline deliveries triggered leaks.

Procedure Used to Estimate Potential Emission Reductions – The emission reductions from real-time monitoring for vapor leaks were estimated as follows:

- **Reduction in Tank Filling Losses** – To estimate the reduction in tank filling losses, the estimated improvement in Stage I efficiency was applied to emission estimates for GDF tank filling losses. Assumptions are shown on Table 4-7. No data has been identified on the improvement in Stage I efficiency from eliminating leaks. ERG's calculations assume that eliminating leaks increases rule effectiveness from 84% to 94%.

Table 4-7. Assumptions for Determining Reductions in Tank Filling Losses for Continuous Monitoring for Vapor Leaks

Parameter	Value
Uncontrolled Tank Filling losses	7.3(lb./1,000 gal)
Stage I Rule Effectiveness Improvement	10% (84% to 94%)

- **Reduction in Breathing Losses** – The reduction in breathing losses from continuously monitoring GDF tanks for vapor leaks was estimated by adjusting the benefit for P/V valves by the fraction of GDFs that are expected to have uncontrolled breathing losses because they have tank vapor leaks. Based on guidance from EPA[18] in 2008, uncontrolled breathing losses are 1.0 lb./1,000 gallons of gasoline dispensed.[19] According to EPA[20], P/V vent caps reduce VOC emissions from underground tank breathing by 90%. GDFs that failed their periodic certification test for pressure decay and/or P/V valve are assumed to have uncontrolled breathing losses. Problems indicated by these types of failures allow vapors to escape to the atmosphere instead of being contained in the GDF tank. Based upon the inspections of GDFs in Massachusetts in 2011, 53% to 76% of the GDFs failed their annual certification test. Based on the results of 120 day certification tests, 85% of the test failures were for the pressure decay or P/V valve tests. Assuming that continuous vapor leak monitoring systems identify these failures on a real-time basis, breathing losses are reduced by 0.41 lb. to 0.58 lb./1,000 gallons. ERG's assumptions are summarized on Table 4-8. Calculated benefits are shown on Table 4-9.
- **Impact of Removing Stage II** -- If Stage II systems are removed, it is possible that leaks will be reduced, thereby reducing filling and breathing losses. If so, the estimated benefits

[18] AP42 -- Transportation And Marketing Of Petroleum Liquids – USEPA, 6/2008
[19] See the discussion of alternative emission factors following Table 4-10.
[20] EPA's July 19, 2000 letter from David Conroy (EPA) to David Wackter (CT DEP)

shown on Table 4-9 for continuously monitoring GDF tanks for vapor leaks could be overstated. MassDEP could further refine the emission estimates by collecting additional information on why GDFs fail pressure decay tests. This would help determine the benefits of vapor monitoring systems after Stage II hardware was removed. However, as noted later in Section 4.3.2, the cost per ton of VOC reduction for this measure, using the emission benefits on Table 4-9, is low at $1,000. Even if benefits are overstated by a factor of two, which is unlikely, the cost per ton still would be low, $2,000 which is far below the costs to control other sources of VOC emissions.

Table 4-8. Assumptions for Determining Reductions in Breathing Losses for Real Time Monitoring of Tank Pressure

Parameter	Value
Breathing losses	1.0 (lb./1,000 gal)
P/V Valve Effectiveness	90%
Fraction of GDFs with vapor leaks	45% to 65%
Benefit for continuous vapor leak monitoring systems	0.41 to 0.58 (lb./1,000 gal)

Table 4-9. Emission Reductions for Continuous Monitoring for Vapor Leaks

Throughput Category (gal/hr)	# GDFs	Total Annual Throughput	Breathing Loss Reduction (lb./1,000 gal)[21]	Filling Losses (tons/yr)	Breathing Losses (tons/yr)	Total Benefit (tons/yr)	Total Benefit (tons/summer day)
Less than 120,000	598	35,880,000	0.41	12.42	7.34	19.76	0.06
120,000 to 240,000	114	20,520,000	0.46	7.10	4.73	11.83	0.04
240,001 to 500,000	371	137,270,000	0.54	47.50	36.80	84.31	0.28
500,001 to 1,000,000	814	610,500,000	0.54	211.27	164.42	375.69	1.23
1,000,001 to 2,000,000	894	1,341,000,000	0.54	464.06	362.19	826.25	2.71
Greater than 2,000,000	241	771,200,000	0.58	266.88	224.56	491.44	1.61
Grand Total	**3,032**	**2,916,370,000**		**1,009**	**800**	**1,809**	**5.94**

Note that 36% of the GDFs dispense less than 500,000 gallons per year. These stations account for only 6% of the estimated benefits for continuous vapor leak monitoring systems. This may be an appropriate exemption level if the State decides to adopt these requirements. Total calculated emission reductions are summarized in Table 4-10.

[21] Value varies according to percent of GDFs that fail certification tests.

Table 4-10. Emission Reductions for Continuous Monitoring for Vapor Leaks (Tons per Summer Day)

Pollution Source	All GDFs		GDFs with 500,000+ gal/year	
	Tons/yr	Tons/Summer Day	Tons/yr	Tons/Summer Day
Filling losses	1,009	3.31	942	3.09
Tank Breathing	800	2.63	751	2.47
Total	**1,809**	**5.94**	**1,693**	**5.56**

Alternative estimates of the reduction in breathing losses from continuous vapor leak monitoring systems – Veeder-Root, a vendor of continuous vapor leak monitoring systems, and representatives of the oil industry have provided alternative estimates of the reduction in breathing losses from continuous vapor leak monitoring systems.

- **Veeder-Root** – Table 4-11 presents Veeder-Root's estimates of the impact of continuous vapor leak monitoring systems on breathing losses. Using emission factors provided by Veeder-Root, the reduction in breathing losses are calculated to be 855 tons per year vs. 800 tons per year when the estimate is based on EPA's emission factors and the percentage of GDFs with vapor leaks.

Table 4-11. Veeder-Root Estimates of Breathing Loss Reductions for Continuous Monitoring for Vapor Leaks

Throughput Category (gal/yr)	# GDFs	Emissions (lb./1,000 gal)	Total Annual Throughput	Breathing Loss Reductions (tons/yr)
Less than 120,000	598	2.22	35,880,000	39.83
120,000 to 240,000	114	2.22	20,520,000	22.78
240,001 to 500,000	371	1.06	137,270,000	72.75
500,001 to 1,000,000	814	0.69	610,500,000	211.64
1,000,001 to 2,000,000	894	0.52	1,341,000,000	348.66
Greater than 2,000,000	241	0.41	771,200,000	159.64
Grand Total	**3,032**		**2,916,370,000**	**855.30**

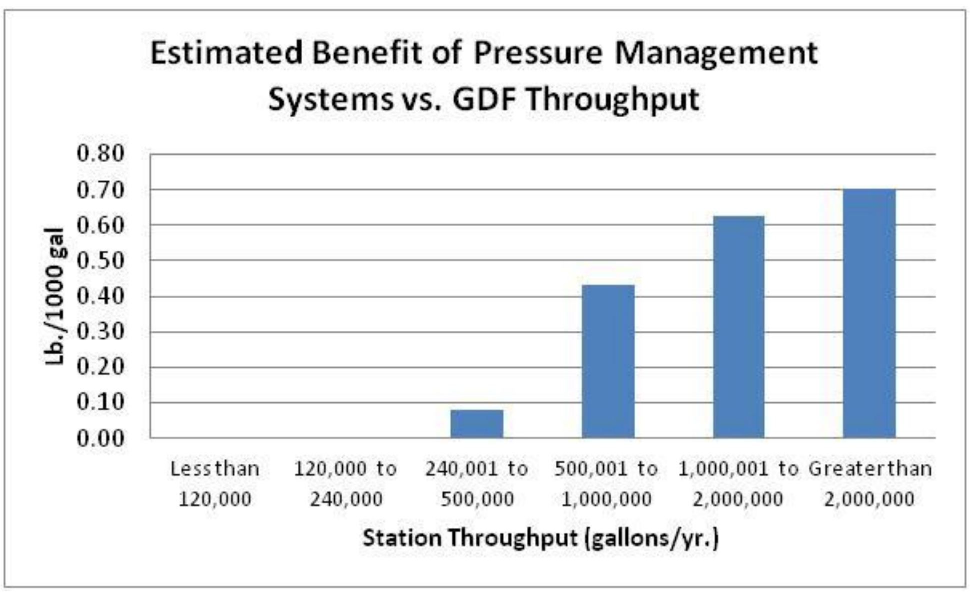
- **Independent Oil Marketers Association of New England (IOMA)** – The IOMA suggested that the emissions factor for uncontrolled breathing losses be reduced to 0.76 lb./1,000 gallons to reflect reduced gasoline volatility during the summer months. EPA's recommended emission factor of 1.0 lb./1,000 gallons is based on tests in 1960's, when the RVP[22] was higher than now. Using an emission factor of 0.76 lb./1,000 gallons instead of 1.0 lb./1,000 gallons reduces the breathing loss benefits by 24%, to 608 tons/year. The calculations for cost per ton of VOC reduced for continuous vapor leak monitoring systems use two breathing loss emission factors: IOMA's factor of 0.76 and EPA's factor of 1.0 lb./1,000 gallons.

4.2.3 Require Pressure Management System (Emissions Processors)

Pressure management systems prevent the buildup of excess pressure in GDF tanks that could cause P/V valves to open and release fuel vapor. EPA has not prepared estimates of the benefits for requiring pressure management systems, but their guidance that P/V valves reduce breathing losses by 90% would imply that pressure management systems will only reduce breathing losses by 10%, or 0.1 lb./1,000 gallons. ERG based benefit estimates for these systems on information provided by vendors of these systems. Two vendors provided estimates based on their internal studies: Veeder-Root and ARID Technologies.

- Veeder-Root – Based on information from Veeder-Root, GDFs will have breathing losses corresponding to the amount of air ingested in the tank and the evaporation rate.
  - Based on in-house Veeder-Root tests at several GDFs, estimated benefits from requiring pressure management systems are greatest in stations that dispense more than 1,000,000 gallons/yr., where benefits are around 0.7 lb./1,000 gallons (see Figure 4-1 and Table 4-12).
  - Exempting stations that dispense less than 1,000,000 gal/yr. will reduce benefits from 2.7 to 2.3 tons/day (17% reduction in benefits), but the number of affected GDFs is reduced by 63%. (See Table 4-13).

Figure 4-1



[22] Fuel volatility and accordingly the potential to emit is based on Reid Vapor Pressure (RVP). IOMA's recommended emission factor (0.76 lb/1,000 gal) is based on theoretical calculations, not on measurements.

Table 4-12. Estimated Emission Reductions for Pressure Management Systems Based on Emission Factors Provided by Veeder-Root

Throughput Category (gal/yr)	# GDFs	Total Annual Throughput	Emission Reduction (#/1,000 gal)	TPY
Less than 120,000	598	35,880,000	0.00	0.00
120,000 to 240,000	114	20,520,000	0.00	0.00
240,001 to 500,000	371	137,270,000	0.08	5.49
500,001 to 1,000,000	814	610,500,000	0.43	132.29
1,000,001 to 2,000,000	894	1,341,000,000	0.62	418.31
Greater than 2,000,000	241	771,200,000	0.70	270.20
Grand Total	**3,032**	**2,916,370,000**		**826.29**

Table 4-13. Breathing Loss Reductions for Pressure Management Controls Based on Data from Veeder-Root

Scenario	Tons per Summer Day
All GDFs	2.7
GDFs with 1,000,000+ gal/yr	2.3

- **ARID Technologies** – ARID Technologies (ARID) provided estimates of the benefits of its Permeator system on GDFs with and without Stage II systems. Unlike Veeder-Root, ARID did not break-out breathing loss reductions from reductions in venting emissions through the tank vent. Also, ARID assumed that GDFs did not have P/V valves. ARID's estimates of emission benefits are much higher than Veeder-Root's estimates for continuous vapor leak monitoring systems and pressure management systems combined. Based on its evaporative loss model, ARID projects a benefit of approximately 4.5 lb./1,000 gallons. ARID's model uses test results from a non-Stage II site as an input.

In contrast to the estimates from these two vendors, the IOMA stated that a CARB certified P/V valve will reduce breathing losses by greater than 99%, in which case pressure management systems will have no benefit. IOMA provided data from a limited test program in Texas to support this claim.

ERG believes that additional research must be performed on GDFs to better define the benefits of pressure management control systems. Connecticut and New York came to similar conclusions and are considering additional research that would involve setting up monitoring systems in leak-free GDFs that measure emissions from P/V valve vents.

4.3 Cost per ton of VOC Reduced for Improvements to MassDEP's Stage I Control Program

4.3.1 Upgrade to CA EVR Module 1 Requirements

Two sources were used to define the costs for upgrading GDFs to meet CA EVR requirements:

- OPW
- EMCO-Wheaton

Costs from these two sources are summarized in Table 4-14. Costs do not include expenses for swivel adaptors, since all GDFs in Massachusetts already have CA EVR adaptors. Actual costs are likely to be lower than costs for the complete CA EVR system, since some GDFs may have other CA EVR certified components, in addition to swivel adaptors. The incremental costs of CA EVR requirements over Massachusetts' current requirements based on cost information from OPW is around $2,000[23], so new or significantly modified GDFs will not incur the full $7,400 cost estimated for new CA EVR components.

Table 4-14. Fixed Costs for CA EVR Phase I Requirements

Source	Fixed Cost (Complete system except for swivel adaptors)
OPW	$8,500 (includes $1,000 for installation)
EMCO-Wheaton	$6,300 (includes $1,000 for installation)
Average	**$7,400 (includes installation)**

Table 4-15 summarizes the cost per ton of VOC reduced for requiring GDFs to meet CA EVR Phase I requirements. MassDEP could reduce the cost per ton of VOC reduced if it allowed GDFs to incrementally upgrade to CA EVR requirements as components are replaced or when facilities are significantly modified, instead of requiring stations to upgrade all components at a fixed time.

[23] OPW estimates CA EVR Phase 1 components cost $8,500 vs. $6,400 for a system meeting MassDEP requirements.

Table 4-15. Cost per Ton of VOC Reduced for CA EVR Requirements

Throughput Category (gal/yr)	# GDFs	Total Annual Throughput	Total Benefit (tons/yr)	Annual Cost[24]	Fuel Savings/Yr	$/ton
Less than 120,000	598	35,880,000	3.29	$719,980	$4,341	$217,279
120,000 to 240,000	114	20,520,000	1.88	$137,254	$2,483	$71,548
240,001 to 500,000	371	137,270,000	12.60	$446,677	$16,607	$34,130
500,001 to 1,000,000	814	610,500,000	56.04	$980,040	$73,860	$16,170
1,000,001 to 2,000,000	894	1,341,000,000	123.10	$1,076,358	$162,239	$7,426
Greater than 2,000,000	241	771,200,000	70.79	$290,159	$93,302	$2,781
All	**3,032**	**2,916,370,000**	**268**	**$3,650,467**	**$352,832**	**$12,318**

4.3.2 Requiring Continuous Monitoring for GDF Vapor Leaks

Three sources were used to estimate the costs of real-time monitoring of GDF vapor leaks (see Table 4-16):

- Veeder-Root: Supporting data provided for proposed New York Part 230 Regulation[25];
- Franklin Fueling Systems: Cost estimates for the vapor leak monitoring portion of its California In-station Diagnostic (ISD) system[26];
- California EVR spreadsheet: Costs for the vapor leak monitoring portion of the California EVR program.

Table 4-16. Costs for Continuous Monitoring for Vapor Leaks

Source	Fixed Cost/GDF
Veeder-Root	$6,000 (includes $1,000 for installation)
Franklin Fuel Systems	$5,000 (includes $1,000 for installation)
California EVR Spreadsheet	$6,105 (includes installation)

ERG used an average of Veeder-Root and Franklyn costs ($5,500) as the basis for the cost per ton of VOC reduced analysis. Cost per ton of VOC reduced values are shown in Table 4-17. As discussed above, exempting GDFs that dispense less than 500,000 gallons per year reduces emission reductions of this measure by only 6%, while exempting these GDFs reduces costs for

[24] Number of GDFs times $7,400 times 0.1627 (capital recovery factor assuming 10% interest and 10 year life).
[25] Personal Communication between Rob Klausmeier, dKC and Kristine Anderson, Veeder Root, Vapor Emissions Workbook, November 8, 2011
[26] Personal Communication between Rob Klausmeier, dKC and Dan Marston, Franklin Fuel Systems, February 29, 2011

this measure by 36%. Also note that stations dispensing more than 2,000,000 gallons per year are estimated to see a net cost savings due to significant fuel savings.

Table 4-17. Cost per Ton of VOC Reduced for Continuous Monitoring for Vapor Leaks

Throughput Category (gal/yr)	# GDFs	Total Annual Throughput	Total Benefit (tons/yr)	Annual Cost[27]	Annual Fuel Savings	$/ton
Less than 120,000	598	35,880,000	19.76	$804,220	$26,040	$39,386
120,000 to 240,000	114	20,520,000	11.83	$153,313	$15,587	$11,646
240,001 to 500,000	371	137,270,000	84.31	$498,939	$111,112	$4,600
500,001 to 1,000,000	814	610,500,000	375.69	$1,094,708	$495,146	$1,596
1,000,001 to 2,000,000	894	1,341,000,000	826.25	$1,202,296	$1,088,961	$137
Greater than 2,000,000	241	771,200,000	491.44	$324,109	$647,695	-$658
All Stations	**3,032**	**2,916,370,000**	**1,809**	**$4,077,585**	**$2,384,542**	**$936**
Stations >500,000 gallons/yr	**1,949**	**2,722,700,000**	**1,693**	**$2,621,113**	**$2,231,803**	**$230**

Table 4-18 presents estimates of the cost per ton of VOC reduced for continuous vapor leak monitoring systems when IOMA's (API's) recommended breathing loss emission factor of 0.76 lb./1,000 gallons is used. Cost per ton are estimated for breathing losses alone, and breathing losses plus filling losses. Cost per ton is much lower for GDFs that dispense more than 500,000 gallons/year.

Table 4-18. Cost per Ton of VOC Reduced for Continuous Monitoring for Vapor Leaks (Alternative Breathing Loss Emission Factors)

Throughput Category (gal/yr)	Breathing Losses Alone		Breathing plus Filling Losses	
	Breathing Losses = 1.0 lb/1,000 gal	Breathing Losses = 0.76 lb/1,000 gal	Breathing Losses = 1.0 lb/1,000 gal	Breathing Losses = 0.76 lb/1,000 gal
Less than 120,000	$108,227	$142,821	$39,386	$43,371
120,000 to 240,000	$31,127	$41,372	$11,646	$13,021
240,001 to 500,000	$12,239	$16,520	$4,600	$5,293
500,001 to 1,000,000	$5,340	$7,442	$1,596	$1,938
1,000,001 to 2,000,000	$2,002	$3,050	$137	$308
Greater than 2,000,000	$125	$581	($658)	($577)
All Stations	**$3,779**	**$5,388**	**$936**	**$1,203**

[27] Number of GDFs times $5,500 times 0.1627 (capital recovery factor assuming 10% interest and 10 year life) plus 10% (annual maintenance factor) times $4,500.

Throughput Category (gal/yr)	Breathing Losses Alone		Breathing plus Filling Losses	
	Breathing Losses = 1.0 lb/1,000 gal	Breathing Losses = 0.76 lb/1,000 gal	Breathing Losses = 1.0 lb/1,000 gal	Breathing Losses = 0.76 lb/1,000 gal
Stations >500,000 gallons/yr	**$2,171**	**$3,273**	**$230**	**$414**

4.3.3 Requiring GDF Tank Pressure Management Systems

Costs for requiring GDFs to be equipped with tank pressure management systems are based on estimates prepared by Veeder-Root for New York State DEC[28]. Costs assume the GDF already has continuous monitoring systems. Fixed costs are shown on Table 4-19. Cost per ton of VOC reduced is shown on Table 4-20. Total costs are reduced by 63% by exempting stations that dispense less than 1,000,000 gallons per year. This exemption reduces emission benefits by 17%.

Table 4-19. Costs for GDF Tank Pressure Management Systems

Parameter	**Costs**
Fixed Cost per GDF (including installation)	$12,250
Annual Maintenance	$1,225

As mentioned previously, ERG believes that additional data must be collected from GDFs to better define the benefits and cost per ton of VOC reduced for tank pressure management systems. Pilot installations of tank pressure management systems (with continuous vapor recovery systems) will help demonstrate the benefits of these systems.

Table 4-20. Cost per Ton of VOC Reduced for GDF Tank Pressure Management Systems

Throughput Category	**# GDFs**	**Total Annual Throughput**	**Total Benefit (tons/yr)**	**Annual Cost[29]**	**Fuel Savings/Yr**	**$/ton**
Less than 120,000	598	35,880,000	0.00	$1,924,962	$0	NM
120,000 to 240,000	114	20,520,000	0.00	$366,966	$0	NM
240,001 to 500,000	371	137,270,000	5.49	$1,194,249	$7,237	$216,182
500,001 to 1,000,000	814	610,500,000	132.29	$2,620,266	$174,352	$18,489
1,000,001 to 2,000,000	894	1,341,000,000	418.31	$2,877,786	$551,311	$5,562

[28] Personal Communication between Rob Klausmeier, dKC and Kristine Anderson, Veeder Root, Vapor Emissions Workbook, November 8, 2011

[29] Number of GDFs times $12,250 times 0.1627 (capital recovery factor assuming 10% interest and 10 year life) plus 10% (annual maintenance factor) times $12,250.

Throughput Category	# GDFs	Total Annual Throughput	Total Benefit (tons/yr)	Annual Cost[29]	Fuel Savings/Yr	$/ton
Greater than 2,000,000	241	771,200,000	270.20	$775,779	$356,108	$1,553
All Stations	**3,032**	**2,916,370,000**	**826**	**$9,760,008**	**$1,089,007**	**$10,494**
Stations >1,000,000 gallons/yr	**1,135**	**2,112,200,000**	**689**	**$3,653,565**	**$907,419**	**$3,989**

4.4 Impact of Stage I Enhancement on Benzene Emissions

Table 4-21 shows the estimated impact of Stage I enhancements on benzene emissions on a summer day.

Table 4-21. Statewide Benzene Emission Reductions (lbs per Summer Day) for Stage I Enhancements

Control Measure	Benzene Reductions (lbs per Summer Day)
CA EVR Phase I	6.85
Continuous Vapor Leak Monitoring System	46.32
Tank Pressure Management System	21.15

4.5 Summary

Following are the major results of the Stage I emissions control analysis:

- Adopting CA EVR requirements is estimated to reduce VOC emissions by 0.88 tons per summer day (TPSD) at an average cost of $12,000 per ton of VOC reduced. Costs per ton of reduction are considerably lower for GDFs with throughput of greater than 1,000,000 gallons per year (~$7,000 per ton). In addition, MassDEP could reduce the cost per ton of VOC reduced if it allowed GDFs to incrementally upgrade to CA EVR requirements as components are replaced or when facilities are significantly modified, instead of requiring stations to upgrade all components at a fixed time.

- Requiring continuous vapor leak monitoring systems is estimated to reduce VOC emissions by up to 6 TPSD at a cost of $1,000 per ton of VOC reduced. It is likely that eliminating Stage II will reduce the number of pressure decay failures. If so, the benefits for continuous vapor leak monitoring systems will be reduced by some undetermined amount.

- Tank pressure management systems have the potential to significantly reduce VOC emissions at a relatively low cost. However, additional data must be collected from GDFs in Massachusetts to better define the benefits and cost per ton of VOC reduced for tank pressure management systems.

5.0 Assessing Impacts on Environmental Justice (EJ) Communities

ERG conducted a preliminary assessment of whether removal of Stage II controls could result in disproportionate air quality impacts in Environmental Justice (EJ) areas. To do this, ERG analyzed whether EJ communities have a greater proportion of non-ORVR vehicles than non-EJ areas. Our analysis determined that EJ communities have a lower proportion of ORVR vehicles (73%) than non-EJ communities (77%), and GDFs located in EJ areas likely dispense a greater proportion of gasoline to non-ORVR vehicles (28%), as compared to GDFs located in non-EJ areas (26%). Both observations suggest that removal of Stage II controls could have a slight disproportionate impact on EJ areas due to refueling emissions. However, other factors (e.g., differences in vehicle miles traveled and fuel economy among the vehicle fleet) suggest that the difference in air quality impacts between EJ and non-EJ areas might actually be lower than these summary statistics imply. The expected air quality impacts associated with removing Stage II controls will likely vary considerably from one municipality to the next, as discussed further in this section. For example, this analysis also revealed considerable variability in the breakdown of vehicles with ORVR controls across municipalities. In municipalities with some designated EJ communities, the percent of ORVR vehicles ranged from 38% to 94%. However, similar variability was observed in municipalities that do not have EJ communities, where the percent of ORVR vehicles ranged from 24% to 94% (based on municipalities that had at least 100 vehicle inspections in 2011).

Assessing how proposed environmental regulations might disparately affect EJ communities is consistent with the spirit of the *Environmental Justice Policy of the Executive Office of Environmental Affairs (EOEA)*. That policy states that "…environmental justice shall be an integral consideration to the extent applicable and allowable by law in the implementation of all EOEA programs, including but not limited to…the promulgation, implementation, and enforcement of laws." The assessment considered here focuses on refueling emissions, which are of health concern due to the fact that they contain multiple hazardous air pollutants. Of particular concern are emissions of benzene, a known human carcinogen that is found in refueling emissions and already accounts for a substantial portion of the nation's cancer risk associated with outdoor air pollution (McCarthy et al., 2009). This assessment considers indicators of refueling emissions, recognizing that the releases of benzene and other air toxics will increase or decrease proportionally with changes in overall refueling emissions.

5.1 Effect of removing Stage II controls on refueling *emissions* in EJ communities

ERG's preliminary assessment indicates that Environmental Justice (EJ) communities have a lower proportion of ORVR vehicles (73%) than non-EJ communities (77%)—a finding based on spatially resolved vehicle inspection data for 2011. ERG further finds that GDFs located in EJ areas likely dispense a greater proportion of gasoline to non-ORVR vehicles (28%), as compared to GDFs located in non-EJ areas (26%). Both observations suggest that removal of Stage II controls could have a slight disproportionate impact on EJ areas due to refueling emissions. However, other factors suggest that the difference in air quality impacts between EJ and non-EJ areas might actually be lower than these summary statistics imply.

5.1.1 Proportion of Vehicles with ORVR Controls

The amount of refueling emissions from a given GDF is a function of multiple parameters, including the quantity of gasoline dispensed, the type of Stage II controls present, and the proportion of ORVR and non-ORVR vehicles that refuel at the station. These parameters are expected to vary throughout the Commonwealth. An evaluation was conducted to assess the extent to which these parameters vary across EJ and non-EJ areas—an important consideration when deciding on whether and when it is appropriate to remove Stage II controls from GDFs.

The ideal data for this evaluation would include the location of all GDFs in Massachusetts, the quantities of gasoline dispensed by each facility, and the proportion of ORVR and non-ORVR vehicles refueling at each individual station. While data are available on the locations and approximate quantities of fuel dispensed at all GDFs in Massachusetts, no GDF-specific data are available indicating the breakdown of vehicles by ORVR controls. Therefore, other data sets had to be evaluated for insights on how the proportion of ORVR and non-ORVR vehicles varies with location across the Commonwealth.

Only one statewide data set—the inspection database generated by the Massachusetts Inspection and Maintenance (I&M) program—documents whether individual gasoline-powered motor vehicles are equipped with ORVR controls.[30] Specifically, during mandatory annual vehicle inspections, inspectors note whether the vehicles they are inspecting have ORVR controls, and this is one of many fields included in the statewide I&M database maintained by MassDEP. The principal limitation associated with using this database is the spatial information provided.[31] For each motor vehicle inspected, the I&M database indicates the location of the inspection station, not the location of where the vehicle is garaged or where it typically refuels. Later sections of this report revisit the significance of this data limitation.

Based on the addresses of inspection stations and records in the I&M database, the breakdown of vehicles by ORVR controls in 2011 was determined for the following three areas:

- 76% (3,256,465 out of 4,274,923) of motor vehicles inspected in 2011 at inspection stations *throughout the Commonwealth* had ORVR controls.
- 77% (2,398,995 out of 3,098,806) of motor vehicles inspected in 2011 at inspection stations *not located in EJ areas* had ORVR controls.
- 73% (857,470 out of 1,176,117) of motor vehicles inspected in 2011 at inspection stations *located in EJ areas* had ORVR controls.

[30] Vehicle registration data maintained by the Registry of Motor Vehicles (RMV) has information on the make and model of all vehicles registered in Massachusetts. However, the RMV database cannot be queried so was not useful for this analysis.
[31] The I&M database also lacks information on the approximately 4% of vehicles registered statewide that fail to receive an annual inspection. No attempts were made to factor in this subpopulation due to the limited availability of data that characterize the potential differences from the standard vehicle population in terms of parameters like total mileage traveled, primary usage location, and frequency of refueling.

This analysis also revealed considerable variability in the breakdown of vehicles with ORVR controls across municipalities. In municipalities with some designated EJ communities, the percent of ORVR vehicles ranged from 38% to 94%. However, similar variability was observed in municipalities that do not have EJ communities, where the percent of ORVR vehicles ranged from 24% to 94% (based on municipalities that had at least 100 vehicle inspections in 2011). Overall, some EJ areas clearly would be expected to have disparate air quality impacts based on the percentage of ORVR vehicles, but this also occurs in certain non-EJ areas. For reference, the ten municipalities in Massachusetts with at least 100 vehicle inspections in 2011 that had the lowest percentage of ORVR vehicles were:

- Hatfield (24% of vehicles have ORVR controls)
- Wareham (38%)
- Colrain (44%)
- Plymouth (47%)
- Warren (48%)
- Shirley (49%)
- Lancaster (50%)
- Ware (50%)
- Plainfield (51%)
- Lakeville (54%)

Only three of the ten municipalities in the previous list contain some EJ neighborhoods. In terms of the larger municipalities with EJ communities, the following had the lowest proportion of ORVR controls: Lawrence (62%), New Bedford (62%), Methuen (62%), and Springfield (63%).

The proportion of ORVR vehicles can be used to predict which municipalities are expected to have the highest air quality impacts once Stage II controls are removed, but only to a first approximation. It is difficult to reach firm conclusions regarding individual municipalities because inspection station data is not a perfect proxy for the proportion of ORVR and non-ORVR vehicles actually refueling in a given community. Moreover, the proportion of ORVR vehicles is one of many factors that affect the anticipated air quality impacts.

5.1.2 Proportion of Fuels Dispensed to ORVR Vehicles

In addition to considering the breakdown of ORVR status in motor vehicles, spatial analyses were used to estimate whether GDFs located in EJ areas dispense more fuel to non-ORVR vehicles. This assessment is based not only on the breakdown of vehicles by ORVR status, but also on the locations of—and quantities of gasoline dispensed at—GDFs throughout Massachusetts. Appendix B of this report documents the detailed data processing steps that were conducted to map the percentages of ORVR vehicles from inspection stations to individual GDFs and any assumptions made about records that should be removed from the analysis. Generally speaking, the data were processed as follows:

- For every GDF, all inspection stations within a 1-mile radius were identified. The 2011 inspection results from all stations within this radius were compiled and the percentage of ORVR and non-ORVR vehicles calculated. It was then assumed that vehicles refueling at the GDFs had the same breakdown of ORVR controls as the local inspection stations, and this proportion was assigned to the annual gasoline throughput recorded for each GDF.

- In the relatively small fraction of cases where no inspection stations were located within 1 mile of a GDF (498 out of 3,032 GDFs total), the percentage of ORVR and non-ORVR vehicles was determined by data from the next closest inspection station that had inspected at least 100 vehicles in 2011 and was not a new car dealership.

- For a small subset of GDFs, spatially resolved ORVR proportions were superseded by an assigned value if the GDF met a certain set of parameters. For example, GDFs located within a half-mile of major roadway (e.g., Mass Pike) exits were assigned the statewide ORVR proportion (76%) due to the expected transient nature of vehicles refueling at the facilities (580 GDFs). On the other hand, GDFs co-located at car dealers and car rental facilities were assigned an ORVR proportion of 100% due to the assumption that all vehicles refueling at these facilities would be equipped with ORVR controls (38 GDFs).

The underlying assumption in this analysis is that the profile of vehicles using a particular GDF is identical to the profile of vehicles that were inspected at nearby stations. This is not a perfect assumption for many reasons (e.g., some commuters refuel their vehicles several miles from their residences), but no other data set available provides better insights into how ORVR controls vary with location in Massachusetts. Additionally, the selection of a 1-mile radius (as opposed to another distance) is somewhat arbitrary, but represents the best professional judgment of MassDEP officials involved in the I&M program.

Based on the data processing steps listed above, the percent of gasoline dispensed to ORVR vehicles was calculated for the following areas:

- 74% of gasoline dispensed at GDFs *throughout the Commonwealth* was to vehicles with ORVR controls. (Note: This percentage differs from the breakdown of ORVR vehicles throughout the Commonwealth for various reasons. For example, vehicles with ORVR controls are known to differ from vehicles without ORVR controls in terms of annual miles traveled, fuel economy, and other important factors.)

- 74% of gasoline dispensed at GDFs *in non-EJ areas* was to vehicles with ORVR controls.

- 72% of gasoline dispensed at GDFs *in EJ areas* was to vehicles with ORVR controls.

As noted previously, Appendix B provides more detailed documentation of the data processing steps used to arrive at these estimates. The appendix also presents specific estimates for the quantities of fuel dispensed at GDFs in EJ areas and non-EJ areas, and the types of Stage II controls typically found at these facilities.

5.1.3 Other Factors Affecting Potential Air Quality Impacts

While the analyses presented in this section are based on the best available information to inform this assessment, some additional observations suggest that the impacts in EJ communities are likely less than indicated above. For example, some evidence suggests that Stage II controls at GDFs in EJ areas already performs less effectively than Stage II controls in non-EJ areas. Specifically, the GDF database indicates that 75% of GDFs in EJ areas failed their initial certification test for Stage II controls, while only 71% of GDFs in non-EJ areas failed this certification. This finding suggests that a greater proportion of the Stage II systems in EJ areas might be providing less effective emission reduction than in non-EJ areas. This is an important observation because the air quality impacts associated with removing less effective controls (such as those found more prevalently in EJ areas) would actually be lower than the air quality impacts associated with removing more effective controls (such as those found more prevalently in non-EJ areas). Moreover, the analyses throughout this section do not take into account the differences between ORVR and non-ORVR vehicles in terms of vehicle miles traveled, fuel economy, and other factors. Therefore, while some statistics point to marginal disparate impacts in EJ communities in terms of the vehicle profile, full consideration of other factors would likely suggest that the disparate impacts are lower, and perhaps minimal.

5.2 Opportunities for Additional Research

ERG's assessment of the potential for disparate impacts on EJ areas was based on the best information available. However, the data used in this assessment have important limitations and uncertainties. These uncertainties might be reduced by conducting follow-up evaluations, such as:

- Sensitivity analysis regarding the effect of using a larger or smaller radius for the GDF and spatially resolved I&M data;
- Distribution analysis to determine the nature and extent of differences in inspected vehicle populations for new car dealers and stations conducting less than 100 inspections per year as compared to the rest of the inspected vehicle population;
- Analysis of the degree to which the type of Stage II controls (i.e., balance or vacuum-assist) installed at each GDF could alter exposures during refueling due to incompatibility excess emissions (IEE);
- Assessment of the differences in annual Stage II certification test results per GDF, and the potential for those to impact GDF-specific refueling emissions; and
- Consideration for field studies to directly measure incremental air quality impacts associated with removal of Stage II controls.

MassDEP may want to consider additional research to analyze the extent to which the suggested percentage difference of ORVR and non-ORVR vehicles in EJ areas might affect ambient air concentrations of air toxics in EJ communities and elsewhere. ERG suggests that such an evaluation should focus on benzene, the "risk driver" for the various HAPs found in refueling vapors. We propose indentifying two or three GDF locations to consider, with at least one being in an EJ area expected to have the greatest air quality impacts. (Note: While EJ areas might be shown to have higher proportions of non-ORVR vehicles, the worst-case air quality impacts may actually occur in non-EJ areas with lower proportions of non-ORVR vehicles but much higher annual gasoline throughput quantities. Proximity of GDFs to residences could be considered when selecting the locations for further analyses.)

ERG recommends some combination of three approaches to assess the ambient air quality impacts resulting from removal of Stage II controls:

- Making inferences about likely ambient air concentrations based on monitoring data published in the scientific literature or by other agencies.

- Using emissions estimates and dispersion models to estimate ambient air concentrations.

- Directly measuring air concentrations during focused field studies.

Following are the exposure scenarios that ERG proposes along with preliminary suggestions for the best approaches to take to characterize exposure concentrations:

- **Scenario 1: Acute exposures among individuals refueling non-ORVR vehicles at GDFs after Stage II controls are removed**. This assessment will consider the highest benzene concentrations expected to occur near pumps during refueling activity and short exposure durations (i.e., the amount of time it takes for an individual to refuel a vehicle). ERG does not recommend using models for this assessment, given the significant uncertainties that would be expected for this particular modeling domain (i.e., modeling breathing zone concentrations in very close proximity to the emission source). The first step we recommend is summarizing data published in the peer-reviewed literature. Our *initial* assessment of this issue has found a broad range of exposure concentrations reported, with some studies reporting short-term benzene concentrations of approximately 30 $\mu g/m^3$ and others reporting short-term benzene concentrations as high as 36,000 $\mu g/m^3$.

- **Scenario 2: Chronic exposures among individuals who routinely refuel vehicles at GDFs after Stage II controls are removed**. This assessment will estimate equivalent chronic exposures based on the intermittent exposures that are expected to occur among individuals who refuel their vehicles at a certain frequency. Once the first scenario is completed and the project team has its upper-bound estimates of short-term exposure during a single refueling event, this scenario can be quickly completed by calculating equivalent exposure concentrations from assumptions regarding the number of times a person refuels per year, the average duration of an individual refueling event, and the longest time frame into the future that one can realistically expect a non-ORVR vehicle to continue to operate. The estimated lifetime exposures could be used for a more thorough assessment of chronic health risks, both for cancer and non-cancer endpoints.

- **Scenario 3: Chronic exposures among residents who live in close proximity to GDFs where Stage II controls have been removed**. This assessment will consider the increased benzene concentrations that might result, as well as the time dependence of the air quality impacts. We propose evaluating this issue first through literature review. After conducting the literature review, ERG would propose considering the utility of dispersion modeling analyses. Modeling is suggested here because most widely-used dispersion models (e.g., AERMOD) are more applicable for evaluating air quality impacts at receptors further away from the sources (as opposed trying to model the acute exposure scenario). Further, this modeling can investigate a wider range of factors that vary across GDFs that could impact the assessment (e.g., type of Stage II controls, fuel throughput, and distance to receptors) but are not as important to the acute assessment. While field studies might also provide valuable insights, monitoring would have to occur over a much longer duration (e.g., possibly 4-6 months) in order to have sufficient data to characterize long-term average changes in air concentrations. Therefore, focused field studies seem more appropriate and cost-effective for informing Scenario 1, and less so for Scenario 3. As with Scenario 2, estimated lifetime benzene exposures could then be used for a more thorough assessment of chronic health risks, both for cancer and non-cancer endpoints.

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Appendix A
Detailed MOVES Outputs for Middlesex and Hampden Counties

Description of MOVES Modeling of Refueling Emissions in Hampden and Middlesex Counties

EPA's Motor Vehicle Emissions Simulator (MOVES) model estimates the evaporative and tailpipe emissions associated with on-road vehicles operating in the U.S., along with their associated energy consumption, for a broad range of calendar years. The model accounts for area-specific factors that directly influence emission levels such as vehicle age distribution, miles traveled per year, fuel specifications (e.g., RVP), and ambient temperatures, among others.

EPA utilized the model, which provided information related to the penetration of ORVR in the national motor vehicle fleet projected to 2020, as the basis for its WSU determination. These model outputs latest were adjusted using MOVES2010a, to be consistent with the latest public release of the model (MOVES 2010a), since that is the version of the model states will use in future inventory assessment work related to refueling emissions control. Overall, ORVR efficiency was determined by multiplying the fraction of gasoline dispensed into ORVR-equipped vehicles by ORVR's 98% in-use control efficiency.

Consistent with EPA guidance, ERG utilized MOVES2010a to estimate vehicle refueling emissions for a variety of scenarios in Massachusetts, using input files provided by MassDEP. ERG calculated emissions reductions for two scenarios, ORVR alone and Stage II alone. Specifically, we estimated VOC and air toxics emissions for the refueling process (benzene, naphthalene, ethanol and MTBE) in MOVES, along with petroleum energy usage estimates (i.e., gasoline consumption in mmBtu). These results allowed us to determine refueling emissions in terms of lbs. of emissions per 1,000 gallons of gasoline dispensed, the commonly accepted units for describing refueling emissions.

ERG developed run specifications for the model, supplemented with modeling files provided by MassDEP which were input to the MOVES County Data Manager. The MassDEP inputs used included the following input tables for both Middlesex and Hampden counties for calendar years 2013, 2015, and 2018:

- Fuels
  - Fuel Formulation
  - Fuel Supply
- Fleet Characterization
  - Source Type Age Distribution
  - Average Speed Distribution
  - Road Type Distribution
  - Ramp Fraction
- Activity Data

  - VMT by HPMS vehicle type category
  - Source Type Population (i.e., all gasoline powered vehicles)
- Activity Fractions
  - Month VMT Fraction
  - Day VMT Fraction
  - Hour VMT Fraction
- Other Inputs
  - I/M Coverage
  - Meteorology

Middlesex and Hampden counties were chosen by MassDEP to represent eastern and western Massachusetts, respectively. These two counties can be used to approximate statewide emissions without the need to model all 14 counties.

MOVES does not provide a simple way to calculate the refueling emissions associated with Stage II controls alone. To remove the effect from ORVR, we ran MOVES for calendar year 1990 using modified 2013/2015/2018 inputs from MassDEP. Since ORVR technology was not introduced for light-duty vehicles until the late 1990s, modeling this calendar year provided a baseline for estimation of refueling emission rates associated with Stage II reductions only. To turn off Stage II controls, the CountyYear table in the MOVES database was edited to set the vapor control program effectiveness to 0%. To estimate the benefits of Stage II alone, the expected control efficiency of 84% that was used in Massachusetts' State Implementation Plan (SIP) was applied to the refueling emissions output by MOVES.

MOVES provides a simple means of calculating emissions associated with ORVR controls alone. Emissions for the ORVR only scenario are calculated by keeping the vapor control program effectiveness set to 0% in the CountyYear table in the MOVES database. The resulting drop in refueling emissions over the calendar years modeled reflects the phase-in of vehicles with ORVR.

Two counties, two scenarios, and three calendar years were modeled, using MOVES county-level annual emissions aggregation, for a total of 12 MOVES runs. Using output from the model, ERG calculated refueling emissions by MOVES source type (e.g., passenger cars and trucks) for each calendar year of interest. Then total emissions for gasoline powered vehicles were calculated by summing emissions across all MOVES source types. The MOVES model runs performed are summarized in **Error! Reference source not found.** Note the "Stage II" scenario oes not include the effects of ORVR, but represents the baseline emission estimates to which the Stage II effectiveness is applied.

Table A-1. MOVES Scenarios Modeled

County	Calendar Year	Scenario	Actual Year Modeled
Middlesex	2013	Stage II	1990
		ORVR	2013
	2015	Stage II	1990
		ORVR	2015
	2018	Stage II	1990
		ORVR	2018
Hampden	2013	Stage II	1990
		ORVR	2013
	2015	Stage II	1990
		ORVR	2015
	2018	Stage II	1990
		ORVR	2018

MOVES emissions outputs were expressed in grams, petroleum consumption in mmBTU, and distances in miles. To convert petroleum consumption outputs to gallons of gasoline, a conversion factor of 115,000 BTUs per gallon of gasoline was used. ERG then calculated refueling emissions in lbs. of VOC per 1,000 gallons of gasoline. These values were then applied to statewide gasoline consumption estimates to calculate statewide refueling emission for the different scenarios. Table A-2 shows the resulting lbs. per 1,000 gallon estimates for Hampden and Middlesex Counties for 2013, 2015 and 2018 for the following scenarios:

1. No ORVR or Stage II
2. Stage II Only
3. ORVR Only

Note that MOVES calculates refueling emissions using the same formula as MOBILE6.2, which accounts for ambient temperature as well as gasoline RVP.

The 2013 results for Hampden County for the first two scenarios appear to be somewhat anomalous, as they are about 3% lower than the 2015 and 2018 results, while for Middlesex County, results for the first two scenarios are identical for all three years, as expected. Note that differences between the counties are solely due to differences in ambient temperature over the year and minor differences in fuel volatility (RVP) from fuel samples taken across the state.

MOVES input run streams, input databases, and output databases were provided electronically for MassDEP review. Modeled refueling emissions and petroleum energy consumption for each of the scenarios listed above are provided in the tables below.

Table A-2. MOVES Results in lbs./1,000 Gallons

Year	Hampden County (lbs. VOC/1,000 gal)			Middlesex County (lbs. VOC/1,000 gal)		
	1. No ORVR No Stage II	2. Stage II Only	3. ORVR Only	1. No ORVR No Stage II	2. Stage II Only	3. ORVR Only
2013	6.58	1.05	1.11	7.14	1.14	1.20
2015	6.78	1.09	0.77	7.14	1.14	0.82
2018	6.78	1.09	0.51	7.14	1.14	0.54

Middlesex County 2013 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25017	11	118,189	3,640,425	-	11,019	30,602,052	281,618,912	1,086,333
1990	25017	21	4,003,896	123,733,072	-	374,509	1,040,122,560	6,139,216,896	36,886,736
1990	25017	31	4,066,680	125,511,136	-	379,892	1,055,069,440	4,117,505,792	37,457,200
1990	25017	32	451,681	13,946,471	-	42,212	117,236,552	456,516,416	4,162,090
1990	25017	43	10,903	336,461	-	1,018	2,828,352	7,803,420	100,840
1990	25017	51	178	5,457	-	17	45,872	83,207	1,630
1990	25017	52	104,445	3,212,447	-	9,723	27,004,376	75,943,904	961,642
1990	25017	53	5,948	182,948	-	554	1,537,898	4,582,606	54,726
1990	25017	54	3,721	114,438	-	346	961,990	2,689,444	34,152
1990	25017	61	6,691	205,629	-	622	1,728,557	2,549,170	61,466

Middlesex County 2013 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2013	25017	11	139,679	4,299,955	-	13,015	36,146,188	281,618,912	1,283,370
2013	25017	21	324,461	10,033,026	-	30,367	84,339,480	6,247,383,040	29,195,696
2013	25017	31	531,495	16,394,160	-	49,621	137,812,432	4,103,566,848	26,048,896
2013	25017	32	64,991	2,005,557	-	6,070	16,859,100	451,677,184	2,848,838
2013	25017	42	251	7,689	-	23	64,638	133,025	2,297
2013	25017	43	812	24,986	-	76	210,039	575,436	7,486
2013	25017	51	179	5,486	-	17	46,116	83,207	1,638
2013	25017	52	28,532	875,298	-	2,649	7,357,915	38,750,980	492,584
2013	25017	53	2,082	63,834	-	193	536,599	2,272,786	27,269
2013	25017	54	2,578	79,039	-	239	664,417	1,844,908	23,581
2013	25017	61	21	656	-	2	5518	7717	197

Middlesex County 2015 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25017	11	117,748	3,626,859	-	10,978	30,488,044	280,552,896	1,082,349
1990	25017	21	3,987,904	123,236,712	-	373,007	1,035,951,680	6,116,005,888	36,740,992
1990	25017	31	4,050,637	125,014,224	-	378,387	1,050,893,120	4,101,928,960	37,311,324
1990	25017	32	449,899	13,891,204	-	42,045	116,772,072	454,790,496	4,145,867
1990	25017	43	10,863	335,216	-	1,015	2,817,879	7,776,010	100,472
1990	25017	51	176	5,417	-	16	45,537	82,606	1,618
1990	25017	52	104,048	3,200,194	-	9,686	26,901,362	75,664,304	958,025
1990	25017	53	5,921	182,118	-	551	1,530,918	4,562,400	54,480
1990	25017	54	3,705	113,958	-	345	957,951	2,678,484	34,011
1990	25017	61	6,666	204,844	-	620	1,721,960	2,539,680	61,235

Middlesex County 2015 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2015	25017	11	139,351	4,289,856	-	12,984	36,061,332	280,552,896	1,280,435
2015	25017	21	205,002	6,341,148	-	19,193	53,304,872	6,222,977,024	28,558,828
2015	25017	31	311,741	9,619,140	-	29,115	80,860,320	4,083,376,896	24,876,690
2015	25017	32	39,274	1,212,440	-	3,670	10,191,994	451,721,280	2,742,134
2015	25017	42	252	7,713	-	23	64,841	133,424	2,304
2015	25017	43	789	24,264	-	73	203,971	558,736	7,270
2015	25017	51	178	5,446	-	16	45,783	82,606	1,626
2015	25017	52	25,913	794,867	-	2,406	6,681,793	38,259,928	486,209
2015	25017	53	1,929	59,155	-	179	497,271	2,234,146	26,800
2015	25017	54	2,460	75,421	-	228	634,002	1,760,266	22,502
2015	25017	61	1	24	-	0	205	280	7

Middlesex County 2018 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25017	11	117,759	3,627,254	-	10,979	30,491,364	280,552,896	1,082,465
1990	25017	21	3,987,904	123,236,712	-	373,007	1,035,951,680	6,116,005,888	36,740,992
1990	25017	31	4,050,637	125,014,224	-	378,387	1,050,893,120	4,101,928,960	37,311,324
1990	25017	32	449,899	13,891,204	-	42,045	116,772,072	454,790,496	4,145,867
1990	25017	43	10,863	335,216	-	1,015	2,817,879	7,776,010	100,472
1990	25017	51	176	5,417	-	16	45,537	82,606	1,618
1990	25017	52	104,048	3,200,194	-	9,686	26,901,362	75,664,304	958,025
1990	25017	53	5,921	182,118	-	551	1,530,918	4,562,400	54,480
1990	25017	54	3,705	113,958	-	345	957,951	2,678,484	34,011
1990	25017	61	6,666	204,844	-	620	1,721,960	2,539,680	61,235

Middlesex County 2018 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2018	25017	11	139,587	4,297,092	0	13,006	36,122,148	280,552,896	1,282,597
2018	25017	21	120,087	3,712,849	0	11,238	31,210,950	6,222,239,744	27,172,598
2018	25017	31	141,199	4,358,116	0	13,191	36,635,100	4,078,237,952	22,953,636
2018	25017	32	18,176	561,380	0	1,699	4,719,073	453,599,712	2,559,292
2018	25017	42	253	7,755	0	23	65,191	134,129	2,317
2018	25017	43	771	23,719	0	72	199,387	546,052	7,107
2018	25017	51	178	5,447	0	16	45,784	82,606	1,626
2018	25017	52	23,924	733,709	0	2,221	6,167,681	38,030,280	483,180
2018	25017	53	1,798	55,131	0	167	463,438	2,213,791	26,552
2018	25017	54	2,348	72,000	0	218	605,246	1,680,131	21,482
2018	25017	61	0	1	0	0	8	11	0

Hampden County 2013 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25013	11	36,922	1,125,505	-	3,407	9,461,196	94,107,032	364,055
1990	25013	21	1,241,883	37,986,472	-	114,975	319,320,800	2,051,511,040	12,279,223
1990	25013	31	1,263,436	38,589,512	-	116,801	324,389,696	1,375,931,264	12,485,615
1990	25013	32	140,318	4,287,407	-	12,977	36,040,700	152,547,696	1,387,210
1990	25013	43	3,388	103,475	-	313	869,826	2,608,744	33,614
1990	25013	51	56	1,691	-	5	14,218	27,996	547
1990	25013	52	32,442	988,039	-	2,991	8,305,635	25,375,090	320,522
1990	25013	53	1,849	56,311	-	170	473,362	1,532,312	18,256
1990	25013	54	1,154	35,143	-	106	295,422	897,112	11,367
1990	25013	61	2,080	63,301	-	192	532,119	851,775	20,505

Hampden County 2013 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2013	25013	11	43,591	1,327,975	-	4,019	11,163,216	94,107,032	429,612
2013	25013	21	100,539	3,077,528	-	9,315	25,870,310	2,087,654,016	9,714,896
2013	25013	31	164,749	5,032,060	-	15,231	42,300,420	1,371,272,576	8,670,176
2013	25013	32	20,143	615,500	-	1,863	5,174,008	150,930,896	948,106
2013	25013	42	78	2,370	-	7	19,921	44,567	767
2013	25013	43	252	7,673	-	23	64,499	192,373	2,492
2013	25013	51	56	1,698	-	5	14,277	27,996	549
2013	25013	52	8,841	268,804	-	814	2,259,621	12,947,850	163,934
2013	25013	53	645	19,618	-	59	164,911	759,964	9,082
2013	25013	54	797	24,236	-	73	203,733	615,401	7,836
2013	25013	61	7	202	-	1	1695	2579	66

Hampden County 2015 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25013	11	37,657	1,152,793	-	3,489	9,690,586	93,548,272	361,958
1990	25013	21	1,266,059	38,905,312	-	117,757	327,045,312	2,039,330,048	12,206,169
1990	25013	31	1,288,169	39,520,672	-	119,619	332,218,112	1,367,752,960	12,411,293
1990	25013	32	143,068	4,391,174	-	13,291	36,913,020	151,649,504	1,379,028
1990	25013	43	3,455	105,994	-	321	891,003	2,593,623	33,419
1990	25013	51	56	1,696	-	5	14,260	27,258	533
1990	25013	52	33,100	1,012,263	-	3,064	8,509,285	25,236,250	318,761
1990	25013	53	1,881	57,522	-	174	483,540	1,519,447	18,102
1990	25013	54	1,178	36,009	-	109	302,697	892,332	11,307
1990	25013	61	2,122	64,818	-	196	544,876	846,710	20,383

Hampden County 2015 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2015	25013	11	44,521	1,361,971	-	4,122	11,448,993	93,548,272	432,262
2015	25013	21	65,011	2,000,108	-	6,054	16,813,280	2,075,000,064	9,584,492
2015	25013	31	98,910	3,035,687	-	9,188	25,518,520	1,361,566,976	8,350,845
2015	25013	32	12,460	382,601	-	1,158	3,216,204	150,625,600	920,454
2015	25013	42	80	2,434	-	7	20,458	44,425	773
2015	25013	43	250	7,660	-	23	64,392	186,362	2,440
2015	25013	51	56	1,703	-	5	14,319	27,258	541
2015	25013	52	8,225	251,032	-	760	2,110,219	12,760,810	163,248
2015	25013	53	611	18,654	-	56	156,807	744,051	8,985
2015	25013	54	780	23,794	-	72	200,014	586,430	7,548
2015	25013	61	0	8	-	0	65	93	2

Hampden County 2018 No ORVR or Stage II

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
1990	25013	11	37,661	1,152,949	-	3,490	9,691,895	93,548,272	362,006
1990	25013	21	1,266,059	38,905,312	-	117,757	327,045,312	2,039,330,048	12,206,169
1990	25013	31	1,288,169	39,520,672	-	119,619	332,218,112	1,367,752,960	12,411,293
1990	25013	32	143,068	4,391,174	-	13,291	36,913,020	151,649,504	1,379,028
1990	25013	43	3,455	105,994	-	321	891,003	2,593,623	33,419
1990	25013	51	56	1,696	-	5	14,260	27,258	533
1990	25013	52	33,100	1,012,263	-	3,064	8,509,285	25,236,250	318,761
1990	25013	53	1,881	57,522	-	174	483,540	1,519,447	18,102
1990	25013	54	1,178	36,009	-	109	302,697	892,332	11,307
1990	25013	61	2,122	64,818	-	196	544,876	846,710	20,383

Hampden County 2018 ORVR Only

Year	County Code	Source Type	Benzene (g/yr)	Ethanol (g/yr)	MTBE (g/yr)	Naphthalene (g/yr)	VOC (g/yr)	Distance (mi/yr)	Energy Consumption (mmBtu/yr)
2018	25013	11	44,596	1,364,258	-	4,129	11,468,210	93,548,272	428,430
2018	25013	21	38,085	1,171,183	-	3,545	9,845,183	2,074,754,944	9,023,246
2018	25013	31	44,797	1,375,285	-	4,163	11,560,907	1,359,850,112	7,624,132
2018	25013	32	5,766	177,136	-	536	1,489,035	151,252,000	850,032
2018	25013	42	80	2,447	-	7	20,569	44,660	769
2018	25013	43	245	7,488	-	23	62,942	182,131	2,360
2018	25013	51	56	1,703	-	5	14,319	27,258	535
2018	25013	52	7,593	231,719	-	701	1,947,876	12,684,210	160,523
2018	25013	53	570	17,384	-	53	146,137	737,272	8,808
2018	25013	54	745	22,714	-	69	190,937	559,733	7,130
2018	25013	61	0	0	-	0	2	4	0

Appendix B. Data Processing Methodology

To estimate the proportion of gasoline dispensed to ORVR vehicles in Massachusetts, and to identify any potential disparities between dispensing proportions in environmental justice (EJ) and non-EJ areas, ERG matched spatially resolved data from Massachusetts' Inspection and Maintenance (I&M) program with MassDEP's statewide data on gasoline dispensing facilities (GDFs). Data were processed and analyzed according to the steps outlined below.

Retrieval and processing of the original datasets

MassDEP provided ERG with an Access database containing tables for 2011 inspection station ("InspStns2011_EJ") and GDF ("Stage2_2011_EJ") data on April 27, 2012. Prior to sharing the data with ERG, MassDEP assigned a status of "EJ" or "not EJ" to each inspection station and GDF based on Census2000 EJ area designations. On May 2, 2012, MassDEP appended additional EJ information to the original data files to create new source files ("InspStns2011_EJ_full_EJ_items" and "Stage2_2011_EJ_full_EJ_items," respectively). The two data sources can be summarized as follows:

I. **Inspection stations:** The inspection stations dataset ("InspStns2011_EJ_full_EJ_items") contains a record for 1,791 inspection stations listed in Massachusetts in 2011. Table fields include the following:
   a. **Station identification:** Station name, location (street address, city, zip, and x-/y-coordinates), and IDs (station ID, assigned FID)
   b. **Inspection data:** The number and percent of ORVR and non-ORVR vehicles—as well as the total number of vehicles overall—inspected in 2011 per facility
   c. **EJ information:** An "EJ"/"not EJ" tag, the specific EJ polygon in which the facility falls ("-1" if not within an EJ area), and additional characteristics regarding the linked EJ polygon

II. **GDFs:** The GDF dataset ("Stage2_2011_EJ_full_EJ_items") contains a record for 3,032 GDFs listed in Massachusetts in 2011. Table fields include the following:
   a. **GDF identification:** GDF name, location (street address, city, zip, and x-/y-coordinates), and IDs (FACACCOUNT, FID_Stage2_2011)
   b. **Refueling data:** Annual throughput (field can be one of six ranges: <120,000; 120,000 - 240,000; 240,001 - 500,000; 500,001 - 1,000,000; 1,000,001 – 2,000,000; and >2,000,000), name and type of CARB Stage II control system, and owner type (i.e., commercial vs. private)
   c. **EJ information:** An "EJ"/"not EJ" tag, the specific EJ polygon in which the facility falls ("-1" if not within an EJ area), and additional characteristics regarding the linked EJ polygon

Inspection station and GDF dataset processing

Following derivation of the source data files, MassDEP and ERG worked to process the datasets such that specific scenarios requiring additional attention were appropriately identified and flagged. Both of the datasets required processing, as outlined below:

I. **Inspection stations:** In order to avoid applying misrepresentative inspection station populations to specific GDFs, sites with certain specific attributes were flagged for additional attention.

   a. **New car dealers:** Operating under the assumption that inspections at new car facilities are unlikely to be representative of the local vehicle population, all new car dealers (228 records) were excluded from the database for calculating location-based ORVR proportions. However, these facilities were included when calculating the statewide proportion of ORVR vehicles. These new car dealers were flagged by MassDEP based on a dataset provided on May 17, 2012, listing all new car dealers that also operated inspection stations in 2011 ("new_car_dealers_with_inspection_stations_thru_2011").
   b. **Less than 100 inspections per year:** Inspection stations conducting less than 100 inspections per year were flagged in the database but not removed. These stations (136 with new car dealers excluded) were only omitted from calculations in the event a GDF did not have any inspection stations located within a mile radius, and thus was paired with the single nearest station. This decision was based on the assumption that while such inspection data is important for overall ORVR calculations, these small stations may not be appropriately representative of an entire area to be used as a stand-alone figure.
   c.

II. **GDFs:** None of the 3,032 originally identified GDFs were removed from the dataset. However, many were flagged as special cases to be handled separately during the subsequent analyses, as explained in the proceeding section.

   a. **Proximity to major roadway exits:** Based on data provided by the Massachusetts Department of Transportation (MassDOT), a half-mile buffer was applied to all major roadway exits across Massachusetts. All GDFs falling within this buffer (567 facilities) were tagged as such, and during subsequent analyses were treated uniquely based on the assumption that the vehicle population frequenting them was highly transient, and therefore unlikely to be represented by local inspection data. An additional 13 GDFs were also treated similarly despite having fallen outside the half-mile buffer, as they were labeled "MassPIKE" or "MassHwy Rest Stop" facilities in the "Stg2_2011_EJ_BusType" table (provided by MassDEP in the Access database "EJ_Stg2_Insp_Analysis_for_ERG" on May 25, 2012).
   b. **Car rentals and car dealers:** GDFs identified as serving car dealers or car rental facilities, as identified by MassDEP in the "Stg2_2011_EJ_BusType" table (provided by MassDEP in the Access database "EJ_Stg2_Insp_Analysis_for_ERG" on May 25, 2012), were flagged as such in the database (38 facilities). Because these facilities are likely to serve only ORVR

vehicles, local inspection data would not be representative of the refueling fleet. Therefore, these facilities were treated as special cases in subsequent analyses.

Linking of GDF and inspection station datasets

To assign specific proportions of ORVR vehicles served to each GDF, MassDEP and ERG established a series of protocols for linking the spatially resolved inspection station and GDF data. Excluding GDFs within the highway buffer and those serving only car dealers and car rental facilities, each facility was matched with inspection station data as follows:

I. **GDFs with inspection stations within a mile radius:** Where facilities existed with inspection stations located within a mile radius, all such stations were linked to the facility. This process was performed by MassDEP and provided in "InspStns2011_EJ_Id_Stg2BuffMile" (from the Access database "EJ_Stg2_Insp_FurtherAnalysis_for_ERG" database shared on May 25, 2012), and applied to 2,534 GDFs.

II. **GDFs with no inspection stations within a mile radius:** Where facilities existed without any inspection stations located within a mile radius, the single nearest inspection station—excluding those conducting less than 100 inspections per year—was linked to the facility. This process was performed by MassDEP and provided in the table "Stage2_2011_EJ_NearestNonDealerGT99InspPerYr" (from the Access database "EJ_Stg2_Insp_FurtherAnalysis_for_ERG" shared on May 25, 2012). "Nearest" station distances applied to 498 GDFs.

From these relationships, ERG developed two composite tables containing the following fields:

I. **GDFs with inspection stations within a mile radius:**
   a. Fields from "Stage2_2011_EJ_full_EJ_items":
      i. *GDF FAC Account:* Unique facility ID, based on "FACACCOUNT"
      ii. *EJ Status:* EJ status according to GDF location, based on "EJ_STATUS" associated with FACACCOUNT
      iii. *Throughput:* Throughput range associated with FACACCOUNT based on "Thru_Put" field
      iv. *Stage II Type:* Stage II control type used at facility based on "CARB_Type" associated with FACACCOUNT
   b. Additional fields based on linked data:
      i. *ORVR Sum <1 mi:* Sum of ORVR inspections ("ORVR_TOTAL" in "InspStns2011_EJ_full_EJ_items") across all linked inspection stations
      ii. *All Inspections Sum <1 mi:* Sum of all inspections ("TOTAL" in "InspStns2011_EJ_full_EJ_items") across all linked inspection stations

iii. *Proportion ORVR:* Calculated value based on the sum of all ORVR inspections divided by the sum of all inspections

c. Additional fields (addressed in next section):

i. Numeric Throughput; Within HWY Buffer; Special Case; Throughput Multiplier; and Amount Dispensed to ORVR

II. GDFs with no inspection stations within a mile radius:

a. Fields from "Stage2_2011_EJ_full_EJ_items":

i. *GDF FAC Account:* Unique facility ID, based on "FACACCOUNT"

ii. *EJ Status:* EJ status based on GDF location, *not* inspection station location; pulled based on "EJ_STATUS" associated with FACACCOUNT

iii. *Throughput:* Throughput range associated with FACACCOUNT based on "Thru_Put" field

iv. *Stage II Type:* Stage II control type used at facility based on "CARB_Type" associated with FACACCOUNT

b. Additional fields based on linked data:

i. *Nearest I/M FID:* Unique inspection station ID based on "FID_InspStns2011_EJ" in "InspStns2011_EJ_Id_Stg2BuffMile" (as shared by MassDEP on May 25, 2012, in the database "EJ_Stg2_Insp_FurtherAnalysis_for_ERG")

ii. *Nearest I/M ORVR:* Number of ORVR vehicles inspected in 2011 at the linked FID, based on the associated "ORVR_TOTAL" value in "InspStns2011_EJ_Id_Stg2BuffMile"

iii. *Nearest I/M Insp Total:* Total number of vehicles inspected in 2011 at the linked FID, based on the associated "TOTAL" value in "InspStns2011_EJ_Id_Stg2BuffMile"

iv. *Proportion ORVR:* Calculated value based on all ORVR inspections divided by all inspections at the station

c. Additional fields (addressed in next section):

i. Numeric Throughput; Within HWY Buffer; Special Case; Throughput Multiplier; and Amount Dispensed to ORVR

Gasoline throughput calculations

To determine the amount of fuel dispensed to ORVR and non-ORVR vehicles, the following equation was applied to each of the 3,032 GDFs:

Equation: ORVR throughput = (annual GDF gasoline throughput) X (proportion of ORVR vehicles)

Where:

I. Each GDF's annual throughput was assigned a numeric value based on the midpoint of its listed range:

a. <120,000: 60,000
b. 120,000 – 240,000: 180,000
c. 240,001 – 500,000: 370,000
d. 500,001 – 1,000,000: 750,000
e. 1,000,000 – 2,000,000: 1,500,000
f. >2,000,000: 3,200,000 *(based on results from 2011 Connecticut Stage II study)*

II. Each GDF's "throughput multiplier" was calculated as follows:
   a. For car rental and car dealer GDFs—even if located within the highway buffer—the percentage of ORVR vehicles was assumed to be 100, so the multiplier was "1"
   b. For those GDFs falling within the highway buffer (including those outside the half-mile buffer but listed as MassPIKE or Mass Highway service stations), the percentage of ORVR vehicles was listed as the overall state percentage for 2011: 76.18% (i.e., multiplier of 0.761759919)
   c. For all other GDFs, the multiplier used was based on the calculated proportion of ORVR vehicles from the linked inspection station(s)

Summary data calculations

To assess potential disparities between refueling vehicle populations in EJ and non-EJ areas, ERG calculated the percent of gasoline dispensed to ORVR vehicles in the two areas respectively. Calculated ORVR throughput values were summed for GDFs in EJ and non-EJ areas, and were also broken out according to the type of Stage II controls in place at the facility. The latter calculations were performed in order to assist considerations of ORVR/vacuum assist incompatibility excess emissions calculations.

Overall, this analysis found a statewide percentage of gasoline dispensed to ORVR vehicles of 73.6 percent in 2011, with EJ areas at 72.1 percent and non-EJ areas at 74.2 percent. By comparison, a strict application of the calculated statewide ORVR percentage would result in an estimated 76.2 percent of all gasoline being dispensed to ORVR vehicles. The analyses outlined here relied on data from 1,564 of the 1,791 inspection stations, and 8,755 instances of an inspection station's data being applied more than once to a GDF's proportion calculations due to the frequent overlap of 1-mile radii.

Table B-1. Data Summary by EJ Area Status

EJ Status	Number of GDFs	Total Gallons Dispensed	Total Gallons Dispensed to ORVR	Percent of Gasoline Dispensed to ORVR
EJ	756	705,710,000	508,610,949	72.07%
Assist	485	594,120,000	427,952,158	72.03%
Balance	271	111,590,000	80,658,791	72.28%
Not EJ	2,276	2,210,660,000	1,639,143,443	74.15%
Assist	1,476	1,929,980,000	1,433,541,410	74.28%
Balance	800	280,680,000	205,602,034	73.25%
All	**3,032**	**2,916,370,000**	**2,147,754,392**	**73.64%**